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ARTHUR SMITH TUTTLE, PRESIDENT,
1910.

THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK

PROCEEDINGS

FOR

1910

Edited by

GEORGE A. TABER, Chairman

PUBLICATION AND LIBRARY COMMITTEE

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CONTENTS.

PROCEEDINGS OF THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.

PAPER NO. 54.—THE HENRY HUDSON MEMORIAL BRIDGE, BY WILLIAM H. BURR, M. M. E. N. Y., CONSULTING ENGINEER, DEPARTMENT OF BRIDGES..... 5

PAPER NO. 55.—THE MANHATTAN BRIDGE, BY ALEXANDER JOHNSON, M. M. E. N. Y., CHIEF ENGINEER, DEPARTMENT OF BRIDGES..... 21

PAPER NO. 56.—THE DEVELOPMENT OF JAMAICA BAY INTO A HARBOR FOR NEW YORK CITY, BY WILLIAM G. FORD, M. M. E. N. Y., CONSULTING ENGINEER, AND MEMBER OF THE JAMAICA BAY IMPROVEMENT COMMISSION..... 42

PAPER NO. 57.—ECONOMIC ASPECTS OF CITY PLANNING, BY BENJAMIN C. MARSH, SECRETARY COMMITTEE ON CONGESTION OF POPULATION IN NEW YORK CITY..... 73

PAPER NO. 58.—STUDIES AND EXPLORATIONS FOR THE HUDSON RIVER CROSSING OF THE CATSKILL AQUEDUCT, BY SAMUEL D. DODGE AND WILLIAM B. HOKE, ASSISTANT ENGINEERS, BOARD OF WATER SUPPLY..... 99

PAPER NO. 59.—THE STREET PAVEMENT PROBLEM IN THE BOROUGH OF MANHATTAN, BY GEORGE W. TILLSON, M. M. E. N. Y., CHIEF ENGINEER, BUREAU OF HIGHWAYS. 136

PAPER NO. 60.—SOME PROBLEMS IN SEWAGE DISPOSAL OF NEW YORK, BY WILLIAM M. BLACK, COLONEL, CORPS OF ENGINEERS, UNITED STATES ARMY..... 164

PAPER NO. 61.—CONSTRUCTION OF THE CROTON FALLS RESERVOIR, NEW YORK CITY WATER SUPPLY, BY FREDERICK S. COOK, M. M. E. N. Y., DIVISION ENGINEER, DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY..... 224

ANNUAL ADDRESS OF THE PRESIDENT..... 260

ANNUAL DINNER..... 324

INSPECTIONS..... 325

MEMOIRS OF DECEASED MEMBERS..... 339

INFORMATION RELATING TO THE SOCIETY..... 341

OFFICERS AND COMMITTEES FOR 1910..... 342

OFFICERS AND COMMITTEES FOR 1911..... 344

PAST AND PRESENT OFFICERS..... 346

AWARD OF PRIZES AND PAST PRESIDENTS' MEDALS..... 348

INDEX TO PREVIOUS VOLUMES OF PROCEEDINGS..... 349

INDEX TO ADVERTISERS..... 355

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 54.

PRESENTED FEBRUARY 23D, 1910.

THE HENRY HUDSON MEMORIAL BRIDGE.

BY WILLIAM H. BURR,* M. M. E. N. Y.

WITH DISCUSSION BY

ARTHUR S. TUTTLE, ALFRED D. FLINN, F. STUART WILLIAMSON, GEORGE A. TABER, EDWARD L. HARTMAN, LEON S. MOISSEIFF, C. V. V. POWERS, CHARLES A. SULLIVAN, MYRON H. LEWIS AND WILLIAM H. BURR.

The proposed Henry Hudson Memorial Bridge, as I presume every member of the Society knows, is designed largely as a reinforced concrete structure, but that does not mean that all parts of the bridge over the 3 000 ft. of its length are of reinforced concrete. The principal reinforced concrete feature is the main arch over the Spuyten Duyvil Creek, having a clear span of 703 ft. and a clear height under the soffit at the crown of about 180 ft.

The approaches are interesting constructions of masonry, but they involve no features of special interest. The spans are circular arches about 108 ft. in the clear. They will be constructed of native stone, *i. e.*, selected gneiss rock as it is found on Manhattan Island.

The foundations offer no special problems. There are rock outcroppings on the southerly side of Spuyten Duyvil Creek throughout the entire length of the Manhattan approach. While the same observation cannot be made with the same emphasis as to the rock on the northerly side, the overlying material there is shallow, perhaps 20 or 25 ft. at most; so that not only for the main span, but also for all parts of both approaches there are excellent founda-

* Consulting Engineer, Department of Bridges.

tion supports on easily accessible bed rock. In fact, as already stated, there is no real foundation problem involved in the actual structure itself, but there is a distinct foundation problem involved in the proper supports of the centering or false-work of the main arch, which will be considered later on.

The consideration of the main span, the reinforced concrete arch of about 725 ft. span between centers of springing joints, or 703 ft. in the clear, will first be taken up. The width of the structure on the upper platform is 80 ft. between the balustrades, *i. e.*, a 50-ft. roadway and two 15-ft. sidewalks. That part of the structure is devoted wholly to roadway and sidewalk purposes. On the deck about 25 ft. below is found the railway platform for four lines of rapid transit tracks. This bridge is not primarily, although actually, an ornamental feature of the northern part of Manhattan Island; it serves a highly useful purpose. It is a part of the rapid transit system ultimately to be built in that part of the City. While it is well called The Henry Hudson Memorial Bridge, it is in reality the utilizing of a feature of the rapid transit system of New York City to memorialize the discoverer of the River, and it is certainly a most admirable and effective kind of memorial; that is, it is not built simply for the purpose of ornamentation, or even of memorialization, but because it is of service to the daily life of the City and it is made a memorial as a part of that system.

The structure, therefore, provides for both roadway traffic on the upper deck and for four lines of rapid transit railway on the lower deck. Those four lines will probably not be constructed at once, as they may not be needed, although they can be so constructed if that procedure should be advisable. These provisions for traffic are supported by spandrel piers carried by the main arch. Reinforced concrete is used throughout this part of the structure, as well as for the main ribs. The latter are 70 ft. wide, 15 ft. thick or deep at the crown, and about 28 ft. at the springing-line. The radius of the intrados, for it is a circular arch, is 485 ft. The possibility of constructing a rib of this span depends upon the radius which can be given to the rib itself. If it were not feasible to use a comparatively small radius for such a purpose, it would not be possible to construct even a reinforced concrete rib of this span. The possibility of constructing a bridge of this type at the

PLATE 1.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BURR ON THE HENRY HUDSON
MEMORIAL BRIDGE.

THE PROPOSED HENRY HUDSON MEMORIAL BRIDGE.

location in question hinged upon the available rise of the arch. Fortunately, it proved to be sufficient. The roadway itself is about 215 ft. above the water and, as already stated, the clear height under the soffit of the arch at the crown is about 180 ft.

It may be interesting to state, in passing, that the approximate computations which were employed to determine the feasibility of building this arched rib, showed that with a corresponding rise the span might reach over a thousand feet. This is not the exact limit of span, because every improvement in material and of fabrication and every other advancement in engineering resource stretches that limit, but with the materials at our command at the present time, and with a proportionate rise it is feasible to build a reinforced concrete arch not less than about 1 000 ft. in span. When it is said to be feasible to build an arch of that span it is meant, not as has frequently been stated even in some engineering journals, that the steel carries the concrete, but that the concrete shall carry itself and the moving load besides. Obviously, the longer the span, when such great lengths are reached, the less the concrete will carry in addition to its own weight, but for the span at which it is feasible to construct the Henry Hudson Memorial Bridge and which is used in the completed plans, the duty of the concrete goes far beyond the carrying of its own weight.

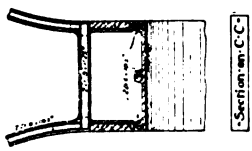
Having settled that main point, the next consideration of importance is the amount, form, and distribution of the steel which will be used to reinforce the rib. This is a matter of the highest importance, and in attacking a problem of this kind it is not easy to determine just what is the best solution, but we have, from experience in reinforced concrete or combined concrete and steel columns, at the present time, enough data to indicate some things of importance. It is believed to be a fundamental requisite for the best and most economical reinforced concrete work that the steel should be so distributed and so formed as to be load-carrying in itself and at the same time to add to the carrying capacity of the concrete by banding it in an effective manner. That has been accomplished in the design of the large arch rib of the Henry Hudson Memorial Bridge.

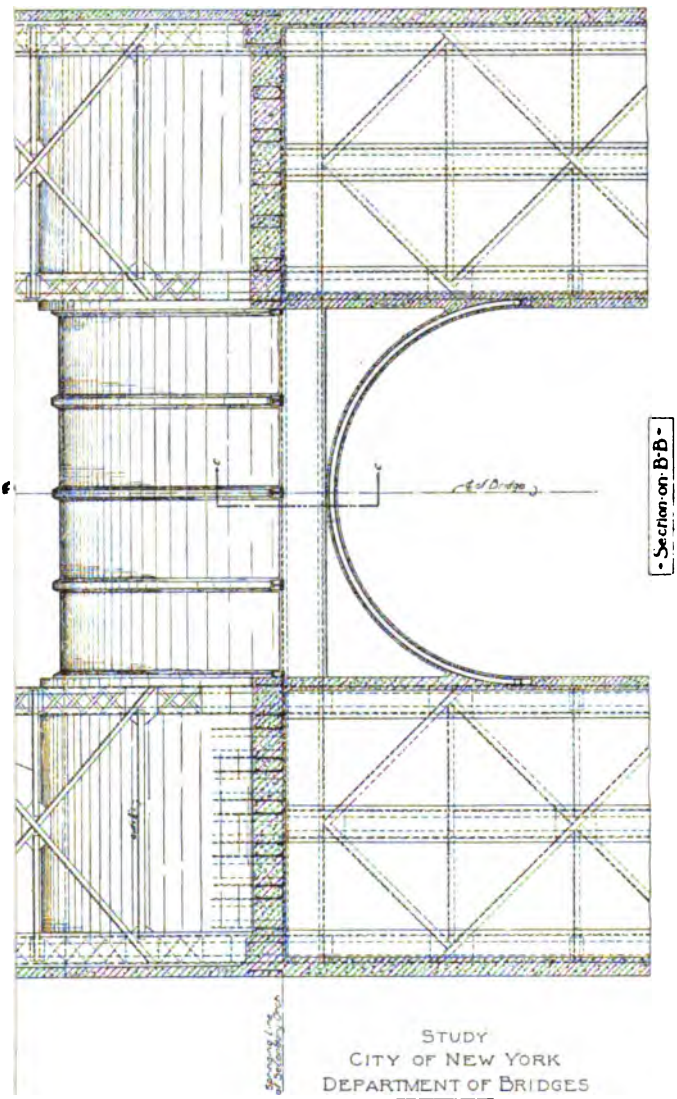
There are distributed throughout the mass of the rib 48 units, as Mr. Moisseiff, who has made the computations for the actual

design of the rib, calls them. There are in each unit four 8-in. by 8-in. steel angles, $\frac{3}{4}$ to 1 in. thick, making the exterior dimensions of the unit 2 ft. 10 in. horizontally and about 3 ft. vertically. The four sides of each of these units are latticed so that the four angles are held rigidly in place. There are four of these units in each vertical line and there are 12 such vertical rows, making 48 units in all, and these are all rigidly connected by bracing both vertically and horizontally. The interlaced network of 48 units with their bracing runs throughout the entire mass of the rib.

When the concrete is put in place in the interior of each of these units, and also between them, and to the exterior line of the rib, about 6 in. outside of the outside units, there will be a combined mass of concrete and steel so rigidly bound together that there is no possibility of its acting otherwise than as a rigid unit. Nearly all of the concrete throughout the entire mass will be efficiently banded. In fact, it may all be said to be firmly banded by these units and the bracing between them. Those units vary in distance vertically, in passing from the crown down toward the springing, because they are uniformly distributed throughout the mass. This brings them such a distance apart near the springing that what may be called "secondary ribs" of angles are introduced there; but they are all held together by both vertical and horizontal latticing and vertical and horizontal bracing, so that the rib itself is an absolutely continuous combined unit extending from one foundation, where the steelwork is carried down to the rock and anchored there, continuously to the other foundation, where the end of the steelwork is again anchored. Indeed it seems impossible to conceive any mass of concrete more solidly banded and held in place and forced to stay precisely where its compression duty requires it to stay in order to perform its work with the greatest efficiency. There is no possibility of any sensible lateral displacement under compression of the concrete. It is, therefore, perfectly justifiable to assume as high a maximum working resistance in the concrete as 750 lb. per sq. in., although as a matter of fact that maximum working resistance under the present plans is really reduced to about 700 lb. The design of this combined mass of steel and concrete has been worked up with probably greater care, with a more thorough study and profound insight of what actually takes place in the rib, than

PLATE 2.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BURR ON THE HENRY HUDSON
MEMORIAL BRIDGE.





STUDY
CITY OF NEW YORK
DEPARTMENT OF BRIDGES

HENRY HUDSON MEMORIAL BRIDGE

CROSS SECTION THROUGH SPANDREL PIERS

any other reinforced concrete structure ever yet either constructed or designed. It is only proper to say that all the work of computation has been carried on under the immediate supervision of Mr. Moisseiff. Not only the stresses due to the direct loading have been computed, but also those due to changes of temperature from one season to another, and to the change of shape due to the removal of the false-work and to varying conditions of loading. In all ordinary arch computations it is customary, as is well known, to assume certain conditions of live loading, such as the whole span, the half span, or possibly five-eighths of a span covered by it. In this case, the stresses due to the actual loading have been computed so as to obtain the absolute maxima due to the moving load to the same extent and degree of accuracy as in an ordinary railroad truss bridge. In fact, the design of this structure really marks an epoch in the analysis of such bridges.

These accurate calculations have sensibly increased the actual stresses over those which would ordinarily be computed. While about 700 lb. per sq. in. is the absolute maximum under conditions of live loading and change of temperature, under ordinary methods of computation there would have been found but about 600 lb. per sq. in. In other words, the ordinary systems of computation would have shown but about 80% of the actual stresses which have been found by the improved methods used in this structure.

The maximum working stress, as has been already stated, will actually be about 700 lb. per sq. in. for the concrete and 20 000 lb. per sq. in. for the steel. The maximum moving load for the entire structure, including both the upper deck and the rapid transit railway deck, will amount to a little over 15 000 lb. per lin. ft., a greater load than has yet been credited as a regular load to any bridge built in this city. There is at least in this structure no constraint as to the prescribed moving load. Not only can the prescribed maximum load be taken as a regular load, but where there is such a high ratio of the dead over the live load, the structure can carry practically any load which may ever be put upon it. It will be one of the most rigid and enduring bridge structures ever built.

There has been undertaken by the Department of Bridges an extensive series of tests of concrete, with varying proportions and

character of aggregate, which show what may reasonably be expected of the concrete to be used. These tests show that a mixture of 1 cement to 6 of sand and gravel, or broken stone, at least equivalent to the old 1:2:4 mixture, will reach an ultimate resistance of 2 600 to 3 000 lb. per sq. in., and in some cases 3 000 to 3 300 lb. per sq. in. at the end of three months. As a matter of fact, it would probably be from one to two years, and perhaps more, before the concrete of this structure would be called upon to carry the full dead load. As city work is ordinarily done, the period in question would probably be materially extended beyond the limits named.

Two of the most difficult problems connected with the design of the work and which will require most careful consideration even throughout the construction, involve the false-work and the method of placing the concrete. Indeed, the placing of the concrete raises some questions of details which cannot be completely set forth before the work is done, as they depend to some extent upon the daily experience of the work as it progresses. It has been decided that the false-work or centering should constitute a distinct part of the contract to be awarded by the City, so that there may be no inducement to the contractors, however efficient or scrupulous they may be, to take any chances or to economize unduly in this part of the construction. The false-work must be of such character that it shall support the construction truly to the desired lines and elevations. Any abnormal or erratic results in this part of the work might create high and undesirable internal stresses, if nothing worse. They might not, and probably would not, affect the ultimate stability or carrying power of the structure, but such conditions would lead to more or less uncertainty and they must be avoided. This necessitates adequate provision for the vertical adjustment of the forms in which the concrete ribs would be placed, so that any needful corrections due to settlement or other similar sources may be made. The plans contemplate for the accomplishment of this purpose the use of a large number of hydraulic jacks of sufficient capacity and so controlled as to meet any exigency of this character which may arise.

The foundation of this centering will be timber piles. A suitable number of experimental or test piles have already been driven to establish the safe carrying power of such foundation members

PLATE 8.
THE MUNICIPAL ENGINEERS
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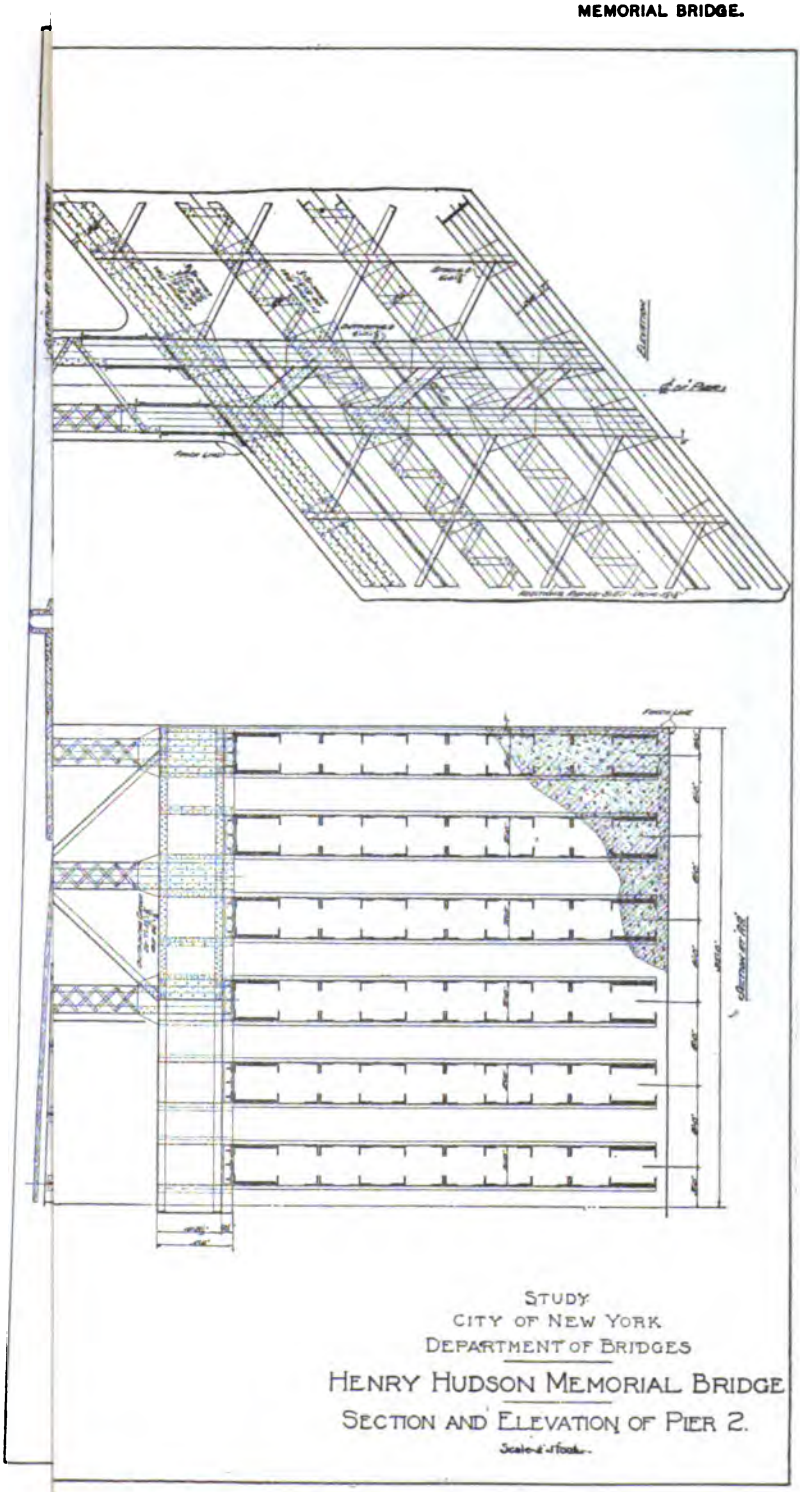
BURR ON THE HENRY HUDSON
MEMORIAL BRIDGE.



STUDY
CITY OF NEW YORK
DEPARTMENT OF BRIDGES

HENRY HUDSON MEMORIAL BRIDGE

SECTION AND ELEVATION OF PIER 2.

Scale 4' / Foot.

at the site of the structure. Timber centering can judiciously be used, except for the 100-ft. truss spans employed to bridge the opening which must be left to accommodate navigation. These trusses carry heavy loads and they will preferably be built of steel.

It will undoubtedly be judicious to keep the false-work timber wet, not only as insurance against fire, but also to prevent shrinkage. The vertical contraction of timber centering as high as that to be used for this purpose would at times be sufficient to make necessary considerable vertical adjustment which may be avoided in a simple manner by keeping the centering wet.

If the steel reinforcement, constituting in itself an arch rib of substantial proportions, were put in place and actually supported upon the false-work while the concrete was being deposited, the greatest compression which could come upon it would be indicated by the ratio between the coefficients of elasticity of steel and concrete, fifteen being the ratio taken. In other words, with 750 lb. per sq. in. on the concrete, the intensity of stress in the steel would be about 11 000 lb. per sq. in. There is, however, a simple way of substantially increasing the compression in the steel by removing the supports on which it is erected so that it shall carry its own weight before the concrete is deposited. The steel thus takes the compressive stress due to its own weight, or to any temporary loading which may be placed upon it, in addition to the product of the compression in the concrete multiplied by the ratio of the coefficient of elasticity of the steel over that of the concrete. This process of giving preliminary compression to the steel may obviously be employed by temporary loading to any desired extent. Furthermore, the false-work is relieved of all loading due to the steel while the concrete is being deposited. It would not be improper to give the steel in this manner a maximum possible working stress of nearly or quite two-thirds of its elastic limit with the grade of steel which would be used in this case.

The spandrel columns or piers which support the upper structure have as their reinforcement actual steel columns of suitable sectional area. That reinforcement therefore is not only of a self-supporting and load-carrying character, but it is in shape to aid substantially the concrete by banding it and preventing undue lateral expansion. Those steel reinforcing parts are brought down

through and riveted rigidly to the 48 reinforcing steel units of the rib with their vertical and horizontal bracing, thus carrying out the fundamental principle that the structure shall be an absolute unit as a whole, *i. e.*, that principle is carried out not only as to the ribs but also as to the superstructure.

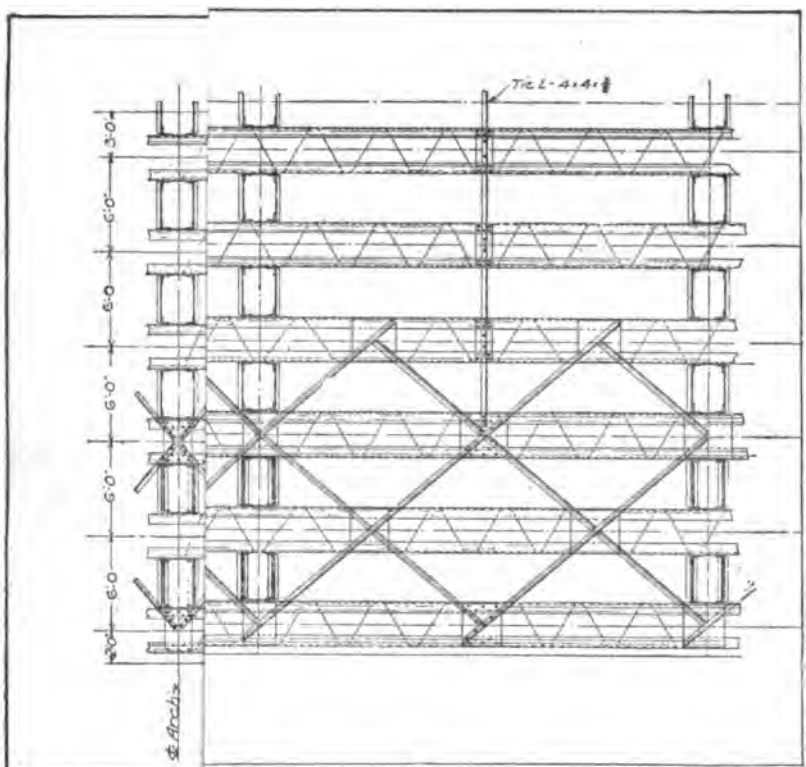
A question has doubtless arisen in the minds of those present as to the end condition of this rib. The answer to such a question probably cannot be made with mathematical accuracy, but it is believed that the ends of the rib may be considered as nearly perfectly fixed as it is possible to make them. The steel reinforcing units are carried down into the bed rock at either end and anchored there. While therefore there evidently will be some slight motion at the ends of the rib in a vertical plane due to varying conditions of loading or to varying temperature, those motions must lie within the elastic limit of the material and be relatively small as the mass of concrete at either end of the rib is large.

It is absolutely essential in such work that the concrete shall be mixed comparatively wet, because it must be so put in place as completely to surround every steel member and form an intimate bond with it at every point. Furthermore, a comparatively wet mixture has the further advantage of producing a much more dense and in every way more satisfactory concrete. Such concrete evidently cannot be rammed, but it should be actively and thoroughly agitated by spades or swords so as to secure complete and intimate contact with the steel reinforcement and work the finer part of the aggregate to the outside of the finished member.

The concrete will be put in place in voussoirs, probably, but not necessarily, of the full depth of the rib and concurrently at such locations along the rib as to secure the greatest attainable freedom from internal stresses at the completion of the work. These voussoirs will be formed by plain sheets of heavy wire netting secured to the steel reinforcement at right angles to the axis of the rib wherever the voussoir joint is to be made. The width of any voussoirs thus formed need not necessarily be the full width of the rib. The wire netting will have meshes of such size that a little only of the finer part of the concrete will find its way through them.

This method of forming the voussoirs or parts of voussoirs by heavy wire netting has many advantages. It is readily and cheaply

PLATE 4.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. BURR ON THE HENRY HUDSON MEMORIAL BRIDGE.



secured to and held in place by the steel reinforcement of the rib. It is not necessary that the netting should be held accurately in a plane surface. Indeed, an irregularity of surface would conduce to a better bond to the next voussoir. Finally, the joint surface of a voussoir thus formed would be rough, and bonding to new concrete would be greatly aided by that roughness. A few tests have been made to determine a suitable size of mesh, but final results have not yet been obtained. Probably ½ to ¾-in. mesh will be suitable. There will be no interior timber or metal forms to be made or handled, it will only be required to wire the netting in place. The latter is comparatively inexpensive and it will aid somewhat in securing the unit character of the rib.

An important feature of the architectural part of the work is the finish of the concrete surfaces of the main arch. Many methods have been tried to secure a variety of effects. The finer parts of the fresh concrete surfaces have been washed away so as to produce a rough surface with the aggregate partially exposed. This operation produces effects considered agreeable and satisfactory from some points of view, but not so satisfactory from others. Again, the hardened surfaces of the concrete masonry have been chiseled to a sufficient extent to give the roughened appearance of stone work, and other measures have been employed in the effort to reach still other effects. This general question has not been finally determined or settled in connection with the main arch of the Henry Hudson Memorial Bridge. It may well be doubted, however, whether any more agreeable or satisfactory surface for a great concrete work of this character can be secured than that of the smooth natural concrete exposed on the removal of the timber forms. Obviously the latter in such a case should be so constructed as to make their surface against which the concrete rests as smooth and true as possible, and those forms should be sufficiently firm and stiff to admit of no distortion by the pressure of the fresh concrete. By spading or properly agitating the concrete in contact with such forms the coarser aggregate can be kept back from the surface, leaving the finer texture ultimately to be exposed. It would seem to be best to accept such concrete work in its true, natural character and permit the smooth concrete surfaces formed by the suitably constructed and supported timber molds to be the exposed surfaces of

the complete structure. It is certainly honest, and honesty is an essential element of both the engineer's and the architect's work.

A bridge of this magnitude and general character must evidently be treated as a great architectural work, as well as an unusual piece of engineering construction. The Department of Bridges has retained Mr. Whitney Warren as Consulting Architect, and the excellence of the architectural features of the structure are due to him and his organization. It has been a matter of great gratification to have the privilege of conferring with him in the design of the structural work, so as to secure proportions and structural features consistent with a suitable architectural treatment of such an unprecedented bridge structure. There has been a most cordial cooperation between the engineering and architectural forces engaged on this design, and it is believed that the results have been unusually satisfactory.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—I am sure that there are a large number present who are interested in the design of this structure, which I believe to be quite unique in many important particulars, and who are prepared to discuss it or who wish to ask questions of the author.

ALFRED D. FLINN, M. M. E. N. Y.—Before the bridge experts begin to ask questions on details, I want to ask a question about the care of the steel work. As I apprehend, a structure of this size will be erected in steel some months before it is all covered with concrete. Is the steel to be painted, or any special precaution taken to prevent rust, or any means resorted to for cleaning it before the concrete is placed? This question is of interest to us in other applications of steel and concrete.

WM. H. BURR, M. M. E. N. Y.—I am very glad that question has been asked, as it had not occurred to me before.

The details of erection have not all been settled, but I think it may be said that the material will not be painted or similarly protected. In fact, it is not clear why anything of the sort should be done in reinforced concrete work. It is, perhaps, a point on which there is room for wide difference of opinion, but so far as my own experience goes, and I have seen a good deal of steel work under various conditions, it may be stated that any coating put on the steel which would be effective in preventing corrosion would certainly render impossible a perfect bond between the concrete and steel. In fact, a little corrosion would not be objectionable. It would simply roughen the surface of the steel without forming a coating. In other words, it would tend to increase the efficiency of the bond rather than otherwise. Loose mill scale should certainly be taken off, but it would be objectionable to paint the steel or give it any protective coating sufficient to keep it from corroding to any sensible extent.

F. STUART WILLIAMSON, M. M. E. N. Y.—I would like to ask the author if he can give us any information as to the proportions of steel in a reinforced concrete span of such magnitude, with the steel that would be necessary in a steel structure of the same span. In looking at the excellent views, the amount of steel seemed to be tremendous, so much so that it is difficult to realize that the structure is really a concrete bridge reinforced with steel.

WM. H. BURR, M. M. E. N. Y.—That computation has not been made, but I may say that the percentage of cross-section of steel in the rib varies from about 3% as a maximum down to about 1¼% as a minimum. How much steel would be required for a steel rib, of

course, is very readily determined by computation, but I know of no computations that have been made.

F. STUART WILLIAMSON, M. M. E. N. Y.—I would like to ask if it is the intention to build up the concrete ribs the full width of the bridge. The author spoke of them, I think, as being built in the manner of voussoirs. Will these voussoirs be the width of the bridge, or will there be longitudinal divisions? It occurs to me that it will be a large mass of concrete to deposit the full width, which, if I remember correctly, is 80 ft. These voussoirs would measure 80 ft. in length, by some considerable thickness. It seems to me that it might be difficult to place so much concrete at one time.

WM. H. BURR, M. M. E. N. Y.—The width of the rib is 70 ft., but 80 ft. is the width of the roadway and sidewalks between the balustrades. In such a great mass of concrete there would be special appliances and machinery for the rapid mixing and depositing of concrete. If it were not desired to make the full 70 ft. width for a voussoir, any part of that width could be employed. Vertical wire netting can be used to hold the concrete laterally for an intermediate part of the rib. All these details would be completely worked out only after the award of the contract. It would, perhaps, be best to make the width of voussoir the entire 70 ft. and prepare the plant for that purpose, but if it were desirable to take half the width or one-third the width, it is perfectly feasible to do so.

F. STUART WILLIAMSON, M. M. E. N. Y.—Having to build a bridge of a much smaller span altogether, the Fulton Viaduct over Dyckman Street, in which it is also proposed to carry the four tracks of a subway, I am interested to know whether the floor of the subway is to be of steel or of reinforced concrete. Also whether the divisions between the tracks are steel posts or solid reinforced concrete walls. I found that in designing this part of the Fulton Viaduct, that the concrete added so much to the weight of the bridge that I decided to use an open steel floor, and steel posts placed 10 or 15 ft. apart.

WM. H. BURR, M. M. E. N. Y.—The outside columns are in the spandrel walls; the intermediate columns are practically of combined steel and concrete, although they might be of steel. The floor of the four railway tracks is of steel.

GEORGE A. TABER, M. M. E. N. Y.—I was very much interested in the portion of the paper in which the author described the proposed forms for the concrete voussoirs. If I understand correctly, it is proposed to make the form of wire netting on the side of the voussoirs at right angles to the axis of the rib, with the idea that a rough surface will therefore be obtained and a good bond secured between the voussoirs.

While that would doubtless give a rough surface and a most excellent bond between the old and new work, it seems to me that as the concrete must necessarily be rather wet, the finer portions would ooze through the meshes of the wire netting and escape, thereby leaving voids near the side of the netting and losing the richer portions of the concrete.

WM. H. BURR, M. M. E. N. Y.—The mortar would not ooze out to any sensible extent, with a mesh suitable for it. In fact we made some experiments on that particular point. It does come out a little and drop down, but that will be cleaned away before the fresh concrete is put in. By determining the proper size of mesh this can be controlled satisfactorily.

EDWARD L. HARTMAN, M. M. E. N. Y.—I would like to ask the author to tell us whether any special plan has been adopted or system devised for keeping the false-work or centers keyed up to the proper position while the concrete is being placed?

WM. H. BURR, M. M. E. N. Y.—Yes, a complete studied design has been made. A system of hydraulic plungers can be used on top of the false-work to jack up the forms so as to keep them at proper elevation wherever needed. That is a part of the work which may be subject to some modification, although a complete plan has been designed by Mr. Moisseiff. In fact, he can best give you the details.

LEON S. MOISSEIFF.—To provide for the control and adjustment of the forms to the true curve desired for the intrados, a system of hydraulic jacks has been provided in the plans for the false-work. These jacks are placed on top of the false-work and bear against rolled steel beams which, in turn, support the planks which make up the bottom floor of the arch forms. The forms rest directly on eight longitudinal rows of beams, which are arranged to be at times supported on about 400 hydraulic jacks of 250 tons capacity each. All of the jacks are, of course, connected with pressure pipes and are generally operated in series of eight jacks, all in a transverse line, thus controlling the entire width of the arch with one motion.

Estimates were obtained from manufacturers of such hydraulic machinery as to the first cost of the required installation and as to its value after using on the work. It is estimated that the cash depreciation would amount to $25 000, an amount which is deemed well worth while expending in view of the advantages derived.

You probably observed, when looking at the cross-sections shown on the screen, that the roadway supporting system consists of rolled steel beams embeded in concrete. This is not reinforced concrete in the correct sense of that term, but it was found to be more reliable and quicker for the purpose, and no more expensive. The I-beams used in the roadway are those utilized previously in supporting the forms.

It is, I believe, a good opportunity to bring out here the amount of preliminary work done on this bridge to provide information for the bidding contractors. It is the aim to furnish the bidders with as much general information as to the conditions of the site and such definite plans and details as is possible to be prepared beforehand. Where the abutment of the main arch is to rest, test pits were dug to rock and specimens of the rock and photographs are available. Where the false-work will have to be erected, test piles, as was explained to you by Professor Burr, were driven to furnish the Department and the bidders with positive information on the actual conditions they will have to meet when driving piles for the false-work. The number of piles required is about 3 300, and with the data available for inspection, the contractor should be able to prepare a conservative bid on this item.

About a thousand concrete cubes, 12 in. by 12 in., and standard cylinders 8 in. by 16 in., of various aggregates, proportions and ages, were made and tested. All of these tests were on untamped concrete and materials bought in the open market. This was done to be able to specify concrete of certain proportions to meet certain requirements of strength in the run of the work.

The false-work for the main arch will also be designed by the Department, and sizes of timbers and details of connections will be specified in the plans. The contractor will be required to follow the plans, but he will, of course, be given the opportunity to improve on them. It is intended to allow to the contractor part payments on the false-work in the same way as is allowed for other parts of the contract. This all is being done to insure the safety of the false-work beyond doubt, and to keep it in the control of the engineers.

C. V. V. POWERS, M. M. E. N. Y.—I am not very familiar with the question asked by Mr. Flinn regarding the feasibility of painting the steel, but in the Rapid Transit work a series of tests was made on that very subject, with the steel imbedded in concrete. We tried painting, or coating it with oil, leaving the rust on and cleaning the rust off, and all the tests showed that the most feasible thing to do was to put the rods in the concrete simply cleaned from the scale. A little rust made no difference, and possibly helped the bond.

CHAS. A. SULLIVAN, M. M. E. N. Y.—I am employed in Long Island City and over there in the approaches to the Pennsylvania Tunnels, a great deal of concrete was used. At every point where there are joints in the wall you will find they are open from ¼ to ⅝ in. In these units, what provision has been made for the extra shear at transverse divisions?

WM. H. BURR, M. M. E. N. Y.—The question may be answered in two parts. The computations, as Mr. Moisseiff can best state, have been made so as to include all possible shear stresses which

can be found in the rib, either where these voussoirs are formed, or at other points. In fact, it may be stated, that no condition of stress has escaped the analysis of the engineering staff of the Bridge Department. Probably the joints mentioned were not in longitudinal compression members. All voussoir joints in this rib would be in heavy compression and I cannot imagine such a thing as an open joint. If the temperature should fall and the length of rib decrease, there would be temperature stresses, which have been provided for fully in the design. There would be no additional shearing stresses in consequence of the joints. It is simply a question whether the shearing resistance at these joints would be satisfactory, but with the peculiarly effective bond which would be formed at these voussoir joints, it is difficult to imagine that there would be any lack of resistance below that of the concrete itself.

LEON S. MOISSEIFF.—I may state that the shearing stresses in general are very small in the main arch rib. The greatest shear in the concrete is found at the abutments and it does not exceed 11 lb. per sq. in. Less than 2% friction is sufficient to overcome this.

As to tension on the concrete, none, of course, is allowed. The line of pressure hugs the neutral line curve so closely that there is no question of the middle-third rule and, consequently, of tension in the rib. The neutral curve, as you have been told by the author, is circular. Considerable study and much labor was spent in trying to obtain the best curve for the arch. A three-centered arch was decided upon, when the consulting architect made some slight changes, and the recomputation showed the curve to be so nearly circular that this simple curve was adopted.

MYRON H. LEWIS, M. M. E. N. Y.—I would like to get some idea as to whether any comparative estimate has been made of the cost of an all-steel bridge—this type of bridge—and an all-stone bridge, in the same location. About what percentage is this type less or more costly than the others?

WM. H. BURR, M. M. E. N. Y.—Perhaps it is sufficient to say that the estimated cost of this structure is about $3 800 000 as now designed. It was originally designed without provision for the rapid transit railroad lines, at about $3 000 000.

LEON S. MOISSEIFF.—I personally do not know that any contract designs were offered to the Department of Bridges. I do know that plans were prepared by the well-known engineering firm of Boller & Hodge, and submitted to the Municipal Art Commission, and that the latter did not approve them. The only complete plans ever prepared by the engineers of the Department of Bridges are those shown to you to-night by Professor Burr.

As to considering the design of an all-stone arch, it was found

from computations that a working pressure of about 1 100 lb. per sq. in. would have to be sustained on the material used. Such stresses are altogether too excessive for voussoir arches with mortar joints, and it was considered unnecessary to prepare an estimate for a granite arch.

Approximately, it may be stated that it would add about a million and a half dollars to the cost of the main span alone to build a satisfactory granite arch of the same dimensions.

Comparing the cost of an all-steel arch to that of the prepared design, I believe that the reinforced concrete bridge will cost about $400 000 to $500 000 more than a steel arch, and have always considered this a good investment, for its good looks and permanency. We should bear in mind that it is desired to erect a structure to serve as a memorial, not only to Henry Hudson, but to the great City of New York.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

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THE MANHATTAN BRIDGE.

BY ALEXANDER JOHNSON,* M. M. E. N. Y.

WITH DISCUSSION BY
ARTHUR S. TUTTLE, WILLIAM J. DUNCAN, GEORGE A. TABER, GARDNER L. VAN DUSEN, MARTIN GAY, GEORGE R. FERGUSON, AND ALEXANDER JOHNSON.

It is not the writer's purpose to present herewith a paper on the Manhattan Bridge. Such paper will later be prepared, when the construction of the bridge is completed and its full use as a highway for traffic is instituted. However, for the information of the Municipal Engineers a few of the more interesting matters connected with the construction of the bridge may be set forth.

It is the fourth bridge built across the East River and marks the close of a remarkable bridge building epoch in the history of the City, beginning in 1895 and continuing through the construction of the Williamsburgh, the Queensboro and the Manhattan Bridges. An era of tunneling under the river ensues, to be followed doubtless by more bridge building, when the present bridges and the tunnels are taxed to their capacity or do not conveniently serve the localities now more sparsely peopled, but with future possibilities of being centers of population.

In 1898 the City began the undertaking of the construction of the Manhattan Bridge. Late in 1899 there had been adopted a general plan for a wire cable suspension bridge with steel towers, masonry anchorages and approach structures of steel viaduct construction. It was to extend from the Bowery and Canal Street in Manhattan to Willoughby Street, between Prince and Gold Streets, in Brooklyn. The bridge of to-day extends from the Bowery and Canal Street in Manhattan to Nassau Street and the Extension of

* Chief Engineer, Department of Bridges.

Flatbush Avenue in Brooklyn. In line with this first general plan were let the contracts for the construction of the tower foundations in Brooklyn and Manhattan, one in 1901 and the other in 1902.

The original general plan of 1899 was superseded in 1903 by a plan for a braced chain suspension bridge. The tower foundations, already contracted for, were adapted to the newer design by additional masonry. Effort was made to introduce desirable architectural treatment of the structure as a whole. Not much could be said in favor of the "lines" of the original plan and it was wisely determined that in the newer plan stern static requirements should be made to combine with beauty of outline.

Controversy arose as to the relative merits of the wire cable and the braced chain suspension bridge, delaying progress in construction. A change in the City administration set aside the braced chain design and in 1904 evolved a new design, haply the final, for a wire cable suspension bridge, which design is carried out in the bridge as it stands to-day. Out of all the controversy, now historic, and by reason of it, has risen the best bridge of its type in the world, a nobly pleasing structure and a highway of capacity second to no other in the world.

As stated before the Manhattan Bridge extends from the Bowery at Canal Street, Manhattan, southeasterly to the Flatbush Avenue Extension at Nassau Street, Brooklyn. The main bridge is a suspension bridge supported by four wire cables hanging in vertical planes stiffened by four trusses, and consists of one river span and two side spans. The cables are supported on steel towers fixed to masonry piers and are anchored in masonry. The approaches on either side of the river are of steel construction, consisting of seven through riveted Warren truss spans supported on concrete piers faced with granite. The Manhattan Plaza or entrance to the bridge will occupy two entire city blocks bounded by the Bowery, Canal Street, Forsyth Street and Bayard Street. The Brooklyn Plaza will occupy two city blocks bounded by Jay Street, Sands Street, Bridge Street and Nassau Street. As these plazas will provide access to the bridge for railway traffic as well as for vehicular and pedestrian traffic, the construction required upon them has not yet been undertaken and cannot very well be until it is known what railway companies are to use the bridge and how.

PLATE 5.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—PONTOON UNDER CONSTRUCTION.

FIG. 2.—CAISSON UNDER CONSTRUCTION.

The bridge, including plazas, has a total length of 6 855 ft., divided as follows: The river span, 1 470 ft. and two side spans each 725 ft., making the total length of the suspended structure 2 920 ft.; the Manhattan Approach is 2 067 ft. long and the Brooklyn Approach 1 868 ft. The Manhattan Bridge is, therefore, third among the suspension bridges of the world in length of river span, it being exceeded by the Williamsburgh Bridge with a river span of 1 600 ft., and the Brooklyn Bridge with a river span of 1 595 ft. 6 in. In every other sense it is a larger bridge than these and of far greater capacity for traffic.

The clear height of the river span for a channel width of 400 ft. is 135 ft. above mean high water, at highest temperature and with the span loaded.

The width of the bridge over all is 120 ft. On the main or lower deck are two footwalks each 11 ft. wide, bracketed outside of each of the outer trusses, the main roadway, 35 ft. wide, extending along the axis of the bridge between the two inner trusses, and four tracks in pairs on either side of the roadway and within the inner and outer trusses. There are two upper deck structures on one level, extending the entire length of the bridge and its approaches, supported by the pair of trusses on each side of the roadway. These provide four more railway tracks in pairs. Eventually there will therefore be in use eight railroad tracks, one roadway and two footwalks.

The railway tracks on the lower deck can be utilized for subway traffic, affording transit between Manhattan and Brooklyn for lines operating the Brooklyn and Manhattan Loop Line, so-called, the Canal Street subway, a possible subway north and south on the Bowery, and the Fourth Avenue (Brooklyn) Subway. In this connection it may be remarked that carrying subway trains out of the ground and lifting them over steep grades through a vertical distance of sometimes over a hundred feet for the purpose of dropping them through the same distance, within the limits of the length of a bridge, appears at best as a makeshift for something that would be better, namely, tubes under the river. If the question be asked as to what would use these lower deck tracks if the subways do not, the existing surface car lines now operating in both Manhattan and Brooklyn and possible additional surface car lines suggest the

answer. The volume of traffic between the two boroughs over existing lines which may be extended is sufficiently great to warrant them the use of the bridge, leaving for future subway routes, existing for the most part as yet only on paper, the use of tubes to be constructed for them, making possible the immediate utilization of existing means of traffic to meet immediate needs, and providing as well for future needs. It is not contended that subway trains should be kept off the bridge altogether, but that operation of them thereon should continue only until the City can divert subway traffic into extensions underneath the river, thereby reducing grades to be traversed, diminishing the chances of accident, lessening costs of operation and increasing efficiency of service. However, the bridge can and will provide four tracks for subway trains. These tracks are practically finished now, except on the Plazas, and will be ready before the subways connecting with them.

While it is thus proposed to utilize all of the lower deck tracks for subways, the surface cars, operating trolley or conduit, may use the four upper deck tracks. These will, of course, have to climb from the streets at the plazas to the bridge deck on track supporting structures of steep grades.

When the track arrangement on the bridge structure was originally determined upon it was assumed that the lower deck tracks would be used by the street surface car lines and the upper deck tracks by elevated railroads. The opposition to further extension of elevated railway structures in the older and more congested sections of the City renders it unlikely that elevated railway trains will ever operate over the bridge on the tracks originally intended for them. It is possible to connect with the elevated railways of Brooklyn in such manner as to bring their trains across the bridge on the lower deck tracks and into a subway in Manhattan. Such arrangement would require extension of the existing elevated railway structure in Brooklyn streets to the bridge plaza.

It has been estimated that with all of the eight tracks on the bridge in use, the railway traffic capacity per hour in one direction will be 180 000 passengers.

The construction work on the bridge was divided into seven principal contracts, as follows:

1. Brooklyn Tower Foundation, let in 1901, completed in 1902.

PLATE 6.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—CAISSON BEING TOWED IN AT PIKE SLIP.

FIG. 2.—CAISSON IN PROCESS OF SINKING.

2. Manhattan Tower Foundation, let in 1902, completed in 1904.

3. Brooklyn Anchorage, let in 1905, completed in 1910.

4. Manhattan Anchorage, let in 1905, completed in 1910.

5. Steel Towers, Cables, Suspenders and Suspended Superstructure, let in 1906, completed in 1909.

6. Manhattan and Brooklyn Approaches, let in 1907, completed in 1910.

7. Roadway and Footwalk Pavements, Electrical Equipment, and Lower Deck Railway Tracks, let in 1909, in course of completion.

The principal contracts remaining to be let are those for the work to be done on the plazas and the installation and equipment of the upper deck tracks.

The tower foundations are practically alike for each side of the river. They are single piers consisting of concrete, limestone and granite masonry. They were carried by means of pneumatic caissons to elevation 91.85 ft. below mean high water in Brooklyn, and elevation 92.26 ft. below mean high water in Manhattan. The Brooklyn caisson rests on a bed of coarse gravel and boulders, the underlying bed rock being but 2 or 3 ft. below the cutting edge. The Manhattan caisson rests on a compact bed of sand and gravel. The underlying bed rock is from 8 to 37 ft. below the caisson. These caisson foundations are now carrying the total dead loads for which they were designed, and there has been practically no settlement of the Brooklyn foundation and a total settlement of about $\frac{5}{8}$ in. in the Manhattan foundation. The maximum pressure under the foundations will be about 8 tons per sq. ft. Under ordinary conditions it will amount to about $6\frac{1}{2}$ tons.

Each caisson was built chiefly of timber and departed from precedent in no essential features except size. The Manhattan caisson is 78 ft. wide, along the axis of the bridge, and 144 ft. long, on the line of the transverse axis of the bridge. The working chamber, divided by two bulkheads into three smaller chambers, was about $6\frac{1}{2}$ ft. high. The timber roof over the working chamber is 2 ft. 9 in. thick. Above this, during construction of the pier, was a timber coffer dam about 50 ft. high. The caissons were built on pontoons located in the Harlem River. When the caissons had sufficiently advanced in construction to be launched the pontoons

were sunk and pulled away from the caissons, which were then towed to the bridge site and moored in position. Concrete above the roof and within the coffer dam was then built up, the caisson settling down into the river bed. Compressed air was then forced into the working chamber and as masonry was added above the roof, material from below was excavated and passed out, the finer material through blow-out pipes and the coarser material through locked shafts which extended upward through the roof from within the working chamber. When the cutting edges of the caissons had reached their final position the working chambers were sealed or filled solid with concrete. The laying of the uppermost courses of granite masonry above the water line to a height of about 32 ft. followed and completed the foundations for the steel towers.

The air pressure employed in the sinking of the caissons varied from 20 lb. to about 47 lb. per sq. in. The total cost of the tower foundations and the granite pedestals surmounting them was $1 125 000.

The anchorages are large masonry structures, one on each side of the river, located about 2 900 ft. apart. They enclose and contain the steel eye-bars and girders which form the anchors for each of the four bridge cables and also the steel anchors for the stiffening trusses at their points of support at the front wall of each anchorage. Each anchorage at its base is about 237 ft. in length and about 182 ft. in width, and at the level of the main deck of the bridge is about 184 ft. in length and about 152 ft. in width. The masonry mass rises to a height of about 103 ft. above street grade, but is finished off architecturally above this by massive granite colonnades about 40 ft. high. Transversely through each anchorage passes a public street, Water Street in Brooklyn, and Cherry Street in Manhattan. The street passage is through a full centered arch 46 ft. in span and rising to a height of about 45 ft. from the pavement. Connecting with this arch at right angles, and on the axis of the bridge, is a smaller arch of about 18 ft. span, forming a passageway through the front face of the anchorage. The most noticeable features in the Manhattan Bridge anchorages, in contrast with the anchorages of the Brooklyn and Williamsburgh Bridges, are the buttressed construction of the front wall and the fact that the cables supporting the bridge are not led into the anchorage through openings

PLATE 7.
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OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—MANHATTAN TOWER PIER, FROM THE EAST RIVER.

FIG. 2.—MANHATTAN TOWER PIER, FROM SOUTH STREET.

PLATE 8.
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OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—PILING AT WEST END OF MANHATTAN ANCHORAGE.

FIG. 2.—BROOKLYN ANCHORAGE, LOOKING NORTHEAST.

in this wall. These features are incidental to a controlling feature in the architectural design of the bridge, namely, that at no point between the anchorages should the cables intersect the line of the stiffening trusses. The cables, extending to the anchorages above the top chords of the stiffening trusses are supported at the front of each anchorage on cast steel saddles bearing on inclined granite pedestals. The buttresses in the front walls of the anchorages are in the planes of the main cables and buttress the pedestals over which the cables are deflected into the anchorages through the surface masonry at the top.

The exterior walls of each anchorage are of granite throughout, relieved by arches, buttresses, pilasters, cornices, balustrades and colonnades in such manner as to form a most pleasing architectural monument, inclosing the more prosaic though more vital construction within of stone, concrete and steel to which are secured the bridge cables.

The Brooklyn anchorage is founded on a bed of sand, gravel and boulders at an elevation of 12 ft. below mean high water. A few bearing piles were driven into this material. The Manhattan anchorage is founded on a bed of sand and on bearing piles at elevation 12 ft. below mean high water. The excavation required for the foundations was all open. On the bearing piles and bottom as cleared was deposited a solid mass of concrete up to the street level, making a masonry footing about 25 ft. thick. This, under the main arch, was reinforced with steel bars. Imbedded in the concrete to the front and rear of the main arch were large blocks of granite and limestone, roughly cubical in form and constituting so-called cyclopean masonry backing. Above the footing the outer walls of granite were laid as the deposit of concrete and cyclopean masonry backing within progressed. The rear portion of the anchorage, resisting the pull of the cables, is built up solidly. In this is imbedded, above water level, the anchor chain girders and the eye-bars forming the anchor chains to which are attached the strands of the wire cables. There are nine groups of chains to each cable, eight in four-strand groups, each composed of 32 eye-bars 9 in. by $1\frac{7}{16}$ in. and one in a five-strand group composed of 42 eye-bars 9 in. by $1\frac{7}{16}$ in.

The front portion of each anchorage, that which supports the

load of the cable saddles and their granite pedestals, is built up solidly through the section of each buttress, with concrete and cyclopean masonry. The middle portion of each anchorage, above the main arch, is divided into chambers, separated by concrete walls supporting concrete arch construction carrying the bridge roadways.

The time allowed the contractor for the construction of the anchorage was divided into two periods between which occurred the building of the bridge cables. The first division of the work involved construction of the rear portion of the anchorage up to elevation 83 ft. above mean high water, and of the front wall, buttresses and pedestals complete.

This arrangement was necessary in order to provide free space for plant and access to the anchor chains during the cable-making operations. Following these the anchorages were completed simultaneously with the completion of the steel spans.

The weight of each anchorage is 231 600 tons. The calculated pressure at the toe under maximum loadings will be about 7.5 tons per sq. ft.

The cost of the Brooklyn anchorage was $1 237 642.35, and of the Manhattan anchorage $1 258 671.50.

The steel towers, cables; suspenders and the suspended superstructure were all included in one contract, the largest of those let in connection with the construction of the bridge. The experience undergone in the construction of the Williamsburgh Bridge where the steel work from anchorage to anchorage was let in three separate contracts, viz., one for the steel towers and shore spans, one for the cables and suspenders and one for the suspended span, clearly implied the wisdom of embracing within the one contract the entire construction of the main bridge and eliminating multiplicity of plant, friction between separate contractors and possible consequent litigation with the City, while at the same time resulting in economy to the City. A very important result, was the gain in time to the City in that the fabrication of all the materials required was proceeding simultaneously and under one direction. This brought about an orderly and intelligent accumulation and erection of materials and fitted each step in the progress of the building of towers, cables and suspended spans in manner to overlap, where possible, succeeding steps, without intervals of time lost

PLATE 9.
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OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—BROOKLYN ANCHORAGE. LOOKING SOUTHEAST.

FIG. 2.—BROOKLYN ANCHORAGE, SHOWING ANCHOR-CHAIN EYE-BARS IN PITS.

PLATE 10.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—BROOKLYN ANCHORAGE, LOOKING WEST.

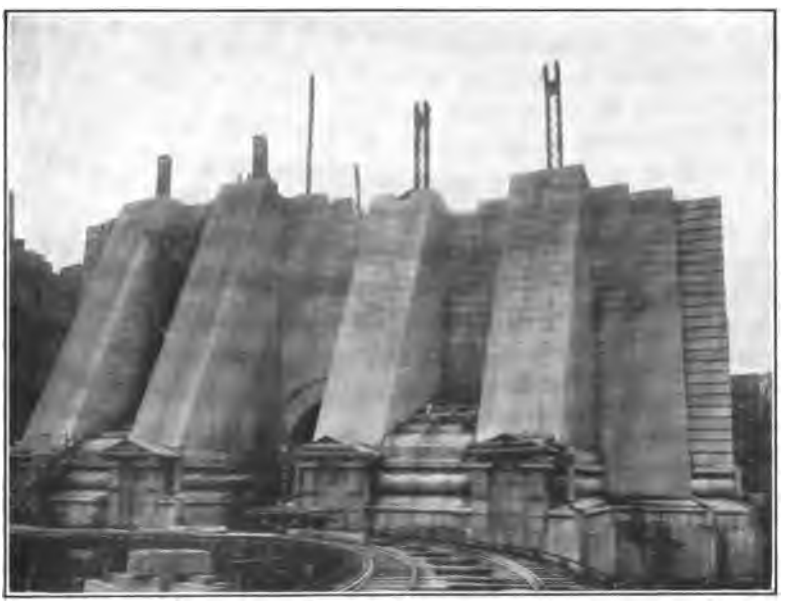


FIG. 2.—BROOKLYN ANCHORAGE, FRONT FACE, LOOKING EAST.

in one contractor waiting for another. In three years and four months there was fully completed the erection of 34 424 tons of structural steel and 8 000 tons of steel wire, suspender ropes and cable bands at a total cost of $6 584 234.83.

The steel towers rise to a height of 336 ft. above mean high water, and consist of four steel columns, one under each cable, braced together and arranged as a transverse bent. Each column is of cellular construction, opposite outer plates or webs being braced together at intervals by transverse diaphragms. The saddles at the top of the towers, on which the cables rest are fixed to the tower, unlike those on the Williamsburgh and Brooklyn Bridges, which rest upon movable bearings. The base of each tower is fixed. As the cables, under varying loads and temperatures, cause movement of the saddles, this movement therefore is taken up by the tower bending inshore or outshore, as the case may be. Under certain conditions of partial loading, and using the working live load of 8 000 lb. per lin. ft. of bridge, adopted in the design of the bridge, the bend at the top of the tower may amount to about thirteen inches, disregarding the resistance to bending developed in the towers themselves as the cable saddles tend to shift. Under similar conditions of partial loading, but using the congested live load of 16 000 lb. per lin. ft. of bridge, the total bend or deflection at the top of the tower may amount to about twenty-four inches. Under these latter assumed conditions, which are not likely to occur in the life of the bridge, no part of the tower would be stressed to more than 0.8 of the elastic limit of the material. Under the severest actual conditions likely to occur the stress developed will not exceed about 0.6 of the elastic limit.

Some very heavy sections were handled in the erection of the 6 250 tons of steel in each tower, the maximum weight being 62 tons. An ingenious feature of this erection was the method adopted by the contractor of supporting the derrick platforms or travellers. No false tower was required, the tower columns themselves forming literally a sort of track up which the travellers moved and by which they were supported as erection progressed. There were two of these travellers, one within each pair of columns. The platform extended inshore from the tower columns, and was supported by two brackets. At the platform level the bracket bore

on rollers which engaged the outstream side of a projecting middle section of the tower column, or where such section did not exist, as in the upper part of the tower, a heavy vertical timber bolted to the tower column. At the foot of the inclined strut of the bracket were rollers engaging the instream side of the projecting middle section. The center of gravity of the traveller complete was, obviously, outside the tower and inshore. The travellers were vertically supported by the projecting heavy gusset plates for the tower bracing. The lower or pedestal section of the towers was erected by floating derricks, and then followed the installation of the travellers, and the erection of the tower columns, the bracing, and finally the cable saddles.

Following the completion of the steel towers and as much of each anchorage as was required for the anchor chains and the support of the anchorage cable saddles, the construction of the bridge cables was undertaken.

There are four cables hanging in vertical planes and located 20 ft. and 48 ft. either side of the center line of the bridge. The wires in the cable are laid straight. There are 9 472 steel wires of 0.192 in. diameter in each cable, laid in 37 strands of 256 wires per strand. The strands are compressed together forming a solid cylinder and are covered with a close wrapping of soft steel wire. The diameter of the finished cable is 21¼ in. The length of each cable from anchorage to anchorage is 3 223.6 ft. Each wire is galvanized and then further protected by a coating of oil. At each panel point of each cable, corresponding to the panel point in the stiffening truss, is securely clamped a cast-steel cable band in which are grooves over which are looped two 1¾-in. galvanized steel-wire ropes, forming thereby four suspenders at each panel point. The lower or free ends of the suspenders are socketed with cast-steel screw-threaded sockets. These sockets pass through heavy steel plates in the bottom chords of the stiffening trusses, engaging large cast-steel nuts on the under side of the chords, forming thus the connection which secures the bridge to the suspenders.

At the tops of the steel towers the cables are supported on heavy cast-steel saddles 11 ft. long, at an elevation 321 ft. above mean high water. As before stated these saddles, one for each cable, are fixed to the towers. The main span of each cable, between

PLATE 11.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN BRIDGE.

FIG. 1.—PEDESTAL IN PLACE ON BROOKLYN PIER.

FIG. 2.—ERECTING STEEL COLUMNS ON MANHATTAN PIER.

FIG. 1.—BROOKLYN TOWER, LOOKING WEST FROM WASHINGTON STREET.

FIG. 2.—SADDLE CASTINGS AT ANCHORAGES.

towers, has a versed sine of 149 ft. at mean temperature and under the dead load of the structure. At the anchorages the cables are supported on cast-steel saddles 30 ft. long, inclined so as to deflect the cable from the catenary curve to the line of the anchor chain. The saddles at the anchorages are placed on cast-steel segmental rollers, taking up the movement of the saddles as caused by the cables. The cables are connected to the anchor chains in strands. The wires in each cable strand are looped over a cast-steel strand shoe, which is secured between two heads of the eye-bars in the uppermost link of the anchor chain by means of a steel pin.

The wire of which the cables are built is made of a high carbon steel, having an ultimate tensile strength in the finished wire of about 210 000 lb. per sq. in. and an elastic limit of about 135 000 lb. per sq. in. The maximum theoretical stress in the cables is about 75 000 lb. per sq. in. The actual maximum stress likely to occur will probably be within 60 000 lb. per sq. in. The breaking strength of each cable is reckoned at 30 000 tons.

The wire of which the suspender ropes were made was of the same quality as that used for the cables. Full size tests of socketed suspender ropes showed their ultimate tensile strength to be about 290 000 lb. The test pieces were 20 ft. long, and the breaks in them occurred within four to eight feet of the socketed end, without failure in the socket. The maximum load ever likely to be carried by one rope in the structure does not exceed 35 000 lb., about one-fourth of its elastic limit.

The stringing of cables was accomplished in a remarkably short time, compared with the only existing precedents, the Brooklyn and the Williamsburgh Bridges. The first cable wire was strung on August 1, 1908, and the last one on December 10, 1908. This satisfactory progress was due to the careful and exact preparations of the Contractor, based on the experience of his Chief Engineer who had already had intimate connection with bridge cables in the design and erection of the Williamsburgh Bridge cables.

Temporary suspension bridges, one for each pair of cables, each with two footwalks or platforms 8 ft. wide, one under each cable, and hanging about 4 ft. below the center line of the completed cable, were first constructed, leading from anchorage to anchorage over the steel towers. Each footbridge was supported on two cables made

up of four 1¾-in. steel wire ropes passing over the steel towers and anchored back at the anchorages. The footbridge construction was of light timber and was stayed by 1¾-in. and ⅞-in. wire ropes anchored to the towers and anchorages. On each of the footwalks were erected nine small timber towers, about equally distant apart, for the support of sheaves over which the hauling ropes passed in their progress back and forth from anchorage to anchorage with the travelling sheaves, or spinning wheels, which drew out the individual cable wires and laid them in place. Timber towers were also erected on the tops of the steel towers, which guided the hauling ropes and travelling sheaves and furnished support for hoists which lifted and adjusted the cable strands into their proper positions in the saddles.

The plant used in stringing the cable wires was in general somewhat similar to that before employed on the Williamsburgh Bridge, but improved in detail and arrangement so as to more than double the working capacity. Work on each cable could proceed simultaneously, the hauling ropes and sheaves for each operating independently. The power plant required was located on the Brooklyn anchorage.

For each cable there was one endless hauling rope to which were attached the two travelling sheaves before mentioned. These travelling sheaves were so arranged that when one was starting from the Brooklyn Anchorage the other would be leaving the Manhattan Anchorage. As each sheave engaged a bight of cable wire there were thus laid four wires at one time in each cable, or when all the hauling ropes were working sixteen cable wires were laid simultaneously. When each bight or loop of wire arrived at the anchorage it was placed upon its proper strand shoe. During the operation of making a strand it was built somewhat higher than the final position required in the finished cable. This was accomplished by attaching each shoe a fixed distance above its final position to a temporary strand leg and also by carrying the strand in temporary supporting sheaves above the saddles on the towers and anchorages. The first few wires in a strand were carefully laid to a guide wire set to computed elevations and checked by observations with instruments. The balance of the wires were laid to these first wires. When all the wires of a strand were laid they were compacted into

PLATE 13.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN BRIDGE.

FIG. 1.—BROOKLYN ANCHORAGE.

FIG. 2.—TOWING FOOT-WALK CABLE ACROSS THE EAST RIVER.

PLATE 14.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

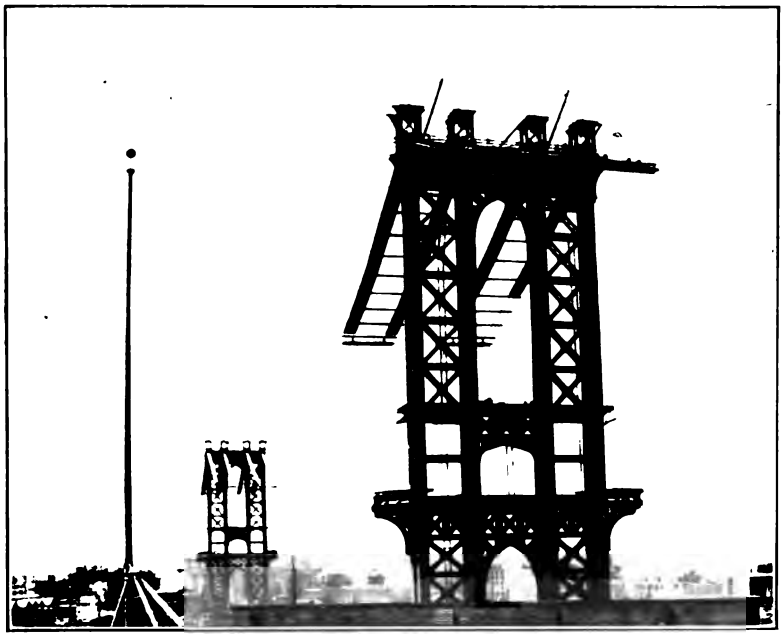


FIG. 1.—BUILDING THE FOOT-WALKS FOR CONSTRUCTION OF THE CABLES.

FIG. 2.—COMPLETED FOOT-WALKS, ON WHICH CABLES WERE CONSTRUCTED.

cylindrical form and seized at short intervals by several turns of wire. These seizings were temporary only, except within the anchorage, and were removed when the completed strands were compacted and rounded into the finished cable. Upon the completion of a strand, the strand shoes were let into their final positions between the eye-bar heads in the anchor chains and the strand was lowered into position in the saddles at the towers and anchorages, being carefully adjusted by means of shims at the strand shoes. The seven strands forming the center of a cable were compacted into a core cable, and the remaining strands were afterward compacted about this core. The cable bands and the suspenders depending from them were then put in place, and afterward the final protective covering of soft steel wire was wrapped about each cable between the cable bands, the ends of which were made water-tight by calking. Fixing hand-rail ropes into position and the application of red lead to all of the construction completed the cable-making.

At the wire mills the cable wire was drawn in lengths of about 3 000 ft. The lengths were spliced together into a continuous wire about 80 000 ft. long and wound on a large diameter shipping reel, the whole weighing about four tons. The wire splice consists of a sleeve $\frac{3}{8}$-in. in diameter having right- and left-hand threads, which engage cold rolled threads on the abutting mitred ends of wire. The field splices required were similarly made. Tests made of the splices developed never less than 95% of the ultimate strength of the wire.

Following the completion of the cables began immediately the erection of the suspended steel spans. The first step involved was the erection of the bottom chords, the floor beams, bottom laterals, main deck stringers, and vertical posts of the trusses.

This was accomplished by means of travellers moving away from the steel towers in both directions. There were in all twelve such travellers, six starting from each tower, three toward the center of the river span and three toward each anchorage. Each group of three travellers consisted of two equipped with one 25-ton derrick each, which erected the heavier members of the floor and moved out over the track stringers within each pair of trusses, and one equipped with a 7-ton derrick, which followed the other travellers.

moving out over the roadway stringers and erecting the lighter material. Erection was carried on so that the loads on either side of each tower and on either side of the center of the river span balanced each other approximately. Inequalities in the loadings and the consequent deflection of the tower were easily detected by means of two heavy plumb-bobs within each tower suspended on wires reaching from the top of tower to the base

When the erection of the lower or main floor of the bridge had been finished the travellers were moved back to the towers and then proceeded away from the towers erecting the web members of the trusses. These erected, the travellers worked back to the towers erecting the top chords of the trusses and the upper deck floors. They were then dismantled at the towers.

During the erection the steel members were delivered to the travellers by cars hauled from the towers over standard gage track laid on the floor as erected. There were fixed derricks at each tower which hoisted material from floats to the cars on the bridge deck.

When all of the principal members had been assembled in the suspended spans, and under the full dead load, the adjustment of the suspenders was commenced and continued until the trusses were suspended in their proper and required positions. The suspenders, before being placed over their respective cable bands, had been accurately cut to required lengths with corrections for stretch under temperature and the dead load, and the adjustments required were therefore relatively small. These were obtained by easing off or taking up the cast-steel nuts engaging the screw-threaded sockets at the ends of the suspender ropes.

The field riveting began after the first adjustment. With the final adjustment made the riveting of the trusses was completed in summer under the desirable condition of high temperature and consequent maximum deflection in the trusses. The rivets driven in the chord splices and in the connections of the diagonal web members to the chords were of nickel steel, of which material were fabricated the main parts of the chords and the diagonal web members, the chord splice plates and the gusset plates for the diagonal connections.

The construction of the steel viaduct approaches, extending from anchorage to terminal plaza on either side of the river, went on

FIG. 1.—VIEW OF ANCHORAGE, SHOWING SYSTEM OF STRINGING CABLES.

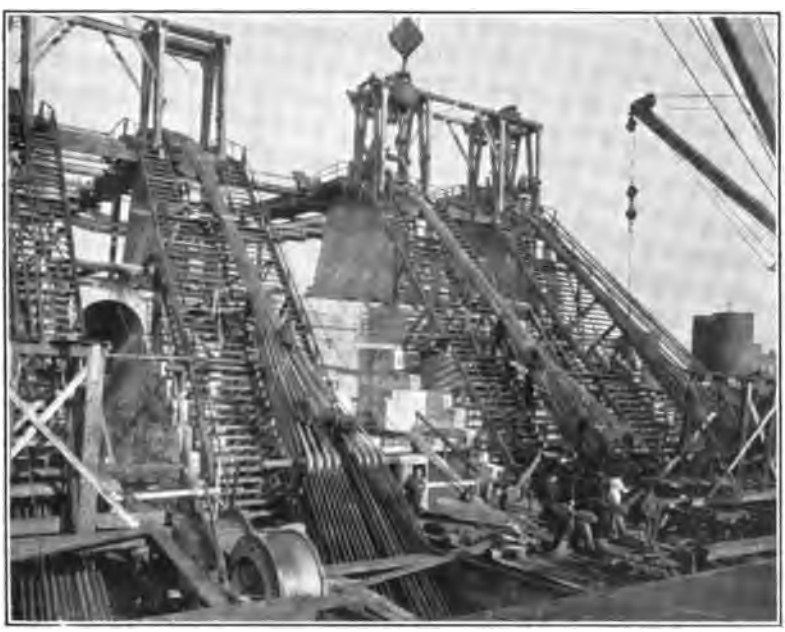


FIG. 2.—VIEW SHOWING CONNECTIONS OF CABLES TO EYE-BARS IN ANCHORAGE.

PLATE 16.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—BROOKLYN ANCHORAGE, WITH CABLES COMPLETED.

FIG. 2.—VIEW SHOWING SYSTEM OF WRAPPING WIRE ON FINISHED CABLES.

simultaneously with the work between the anchorages, under a separate contract. The steel approach on the Manhattan side is 1 293 ft. long from anchorage to the plaza abutment. It is divided into seven spans of through riveted Warren truss construction, five of 189 ft., one of 189.92 ft. and one of 158.08 ft. The varying lengths of span were necessary to prevent encroachment of the supporting piers on existing streets. The steel approach on the Brooklyn side is 1 211.84 ft. long from anchorage to plaza abutment. It also is divided into seven spans similar in construction to those on the Manhattan side, three of 189 ft., two of 189.92 ft., one of 139 ft. and one of 126 ft. The width of each approach is the same as that of the main bridge, 120 ft. The construction follows the same arrangement as obtains there. There are four trusses in each span and roadway, footwalks and tracks on lower and upper decks are placed as in the suspended spans.

The piers on which the steel is supported are built upon concrete footings founded on sand above water level. Above the street surface the piers are faced with granite. The backing is of concrete. Each of the piers is in effect made up of two piers, one on either side of the axis of the bridge and connected at the top by an arch of granite about 28 ft. in span. As at the anchorage, so in these piers, successful effort was made to bring about pleasing architectural result in connection with the more important requirements of utility.

The steel work for the approaches was erected on timber and steel falsework. The bottom chords and the main floor system were first erected. On this floor moved a rectangular tower traveller on which were four 20-ton derricks, one at each corner, by means of which the material was hoisted from trucks on the ground and assembled in the structure. After the floor had been erected the trusses and the upper deck were assembled and the riveting proceeded. The entire cost of the approaches amounted to $2 412 925.66.

In Manhattan, at Division Street, where the Second Avenue elevated railway structure crossed the line of the bridge, it was necessary to lower the street and the railway structure in order to provide sufficient head room for the railroad underneath the floor of the Manhattan Approach. A new railway structure was built and the old railway structure removed without accident to or

interference with the elevated railway traffic. This work was done by the Interborough Railway Company, under a contract with the City.

At the present time the work on the bridge consists of the laying of the lower deck railway tracks and the placing of the footwalk pavements. These lower deck tracks are being laid and equipped for operation by subway or elevated railway trains. The footwalk pavement consists of concrete slabs surfaced with rock asphalt.

On December 31st, 1909, the bridge had been so far completed as to permit its use for vehicle traffic, and the roadway was accordingly opened to the public. The volume of vehicle traffic over the bridge is steadily increasing and bids fair before the end of the current year to exceed that on the Brooklyn Bridge without diminising to any considerable extent traffic there.

The total cost of the bridge structure and the plaza structures when completed will be about $16 000 000. The land acquired for the purposes of the bridge will total in cost about $10 000 000.

PLATE 17.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—VIEW SHOWING CABLES AND SUSPENDERS.

FIG. 2.—VIEW SHOWING ERECTION OF FLOOR SYSTEM ON SUSPENDED SPANS.

PLATE 18.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
JOHNSON ON THE MANHATTAN
BRIDGE.

FIG. 1.—VIEW SHOWING STEELWORK SUSPENDED FROM CABLES.

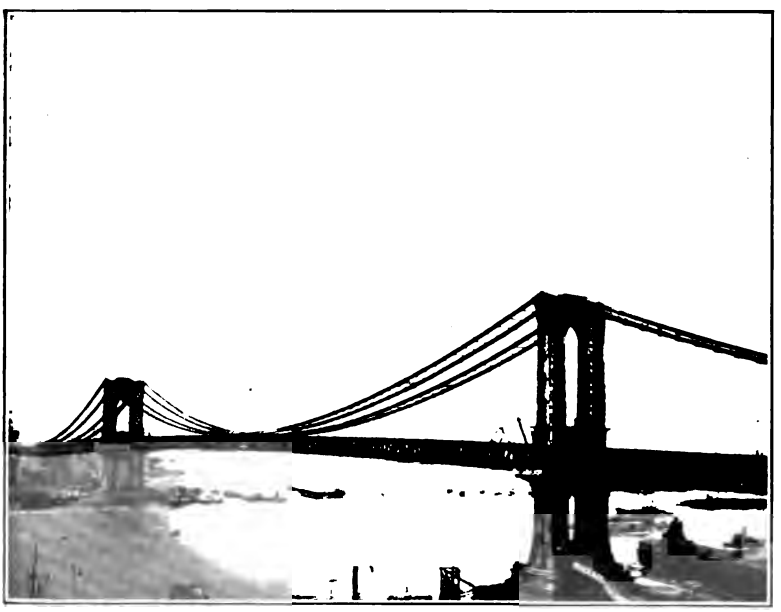


FIG. 2.—COMPLETED BRIDGE. CABLE FOOT-WALKS PARTLY REMOVED NEAR CENTER OF SPAN.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—The subject of this paper introduces a large variety of engineering problems, all of which have been treated by the author as fully as the limits of a general discussion would permit. I have no doubt that there are many present who are desirous of further details concerning certain features of this great structure, and I know that the author will be glad to answer any questions.

A MEMBER.—Mr. Johnson said that the towers were fixed at the base and the saddles were rigidly fixed at the summit of the towers and that the towers moved. I do not quite understand where the motion is taken up due to the load and changes in temperature.

ALEXANDER JOHNSON, M. M. E. N. Y.—The motion is taken up by the bending of the tower. The entire tower will, under extreme variation of load and temperature, bend about 24 in. either way without inducing overstress, and thereby take up all the movement of the saddles, which, in the case of the Williamsburgh and Brooklyn Bridges is provided for by the movement of the saddles on rollers on the tops of the towers.

WILLIAM J. DUNCAN, M. M. E. N. Y.—I would like to ask what pressure was allowed on the soil under the tower piers?

ALEXANDER JOHNSON, M. M. E. N. Y.—The maximum pressure is a little over 8 tons to the square foot.

WILLIAM J. DUNCAN, M. M. E. N. Y.—Is there not some danger that when the tower is deflected one way for some time that there might be an unequal settlement in the soil which would throw the tower permanently out of plumb.

ALEXANDER JOHNSON, M. M. E. N. Y.—No; for the increase in pressure due to such eccentricity in the loading on the soil would not be sufficient to cause any settlement. Eight tons per square foot is a safe and conservative loading.

WILLIAM J. DUNCAN, M. M. E. N. Y.—Somewhat in excess of the building law requirements of the City.

ALEXANDER JOHNSON, M. M. E. N. Y.—The Building Code requirements of the City were intended to fix the regulations regarding foundations on the soil at ordinary building elevations. The building regulations are designed for the purpose of specifying the proper precautions in building structures which possibly may be affected by some deep foundation operation near at hand. The contention that the Building Code should be followed in designing deep foundations is a fallacy; ordinary sand at a depth of 60 or 70 ft. below mean high water level might carry safely 15 tons to the square foot, but you would not think of putting that load on sand at a higher level where that sand might be affected by movement due to an adjoining excavation.

A MEMBER.—I would like to ask why all the trusswork is suspended. On the Brooklyn Bridge a certain number of the panels are carried on struts resting on the cables.

ALEXANDER JOHNSON, M. M. E. N. Y.—The Brooklyn Bridge is suspended on the cables from anchorage to anchorage. The member by which the load is carried to the cable is a little different near the anchorages on the Brooklyn Bridge, of necessity, where the line of the cable is below the line of the floor of the bridge and there the load is transmitted from floor to cable through a short column. In the Manhattan Bridge the cable at no point intersects the line of the truss, and wire-rope suspenders may be used throughout.

ARTHUR S. TUTTLE, M. M. E. N. Y.—It has always seemed unfortunate that in the building of our bridges the City has not heretofore been able to make terms for the operation of the railroad facilities provided, until after the work was completed. As a result of this treatment the municipality has invariably been placed in such a position with reference to the limited competition that it must either accept the terms offered or lose some of the advantages which the improvement was intended to provide. I believe that the powers which have now been given to the Public Service Commission will make it hereafter possible to give ample consideration to the railroad use prior to construction.

ALEXANDER JOHNSON, M. M. E. N. Y.—As to planning the traffic lines, knowing just what lines will use a City bridge before you build the bridge, I doubt very much if that can ever be done. You can plan, of course, but you cannot be sure that your plans will ever be followed out. In the case of the Manhattan Bridge it was a well-conceived plan that the bridge would be built for the purpose of accommodating elevated railway traffic and surface railway traffic. The wide street in Brooklyn, known as the Flatbush Avenue Extension, was acquired by the City for the purpose of providing space on which to place an elevated railway structure that should approach the Manhattan Bridge. We know that now there is little likelihood of any elevated railway structure being put on the street which was acquired for that purpose. Lack of co-operation between public officials and lack of power on the part of these officials have contributed to bring about the situation stated by Mr. Tuttle. Both of these lacks seem in a fair way of being supplied in the near future.

GEORGE A. TABER, M. M. E. N. Y.—As the individual wires which form the strands of the cable were laid two at a time, I would like to ask the author just what method was employed in making those wires the proper length and securing in them the same tension as in the other wires of the cable?

ALEXANDER JOHNSON, M. M. E. N. Y.—The uniform tension in the wire, allowing that the point of support of each wire was approximately the same, would, of course, be indicated by the position of the wire. If the wires were all in approximately the same position or curve, it is proper to assume that they were all under approximately the same tension. In order to bring about that proper position, when each strand was started a guide wire was run across from anchorage to anchorage; that guide wire was very carefully suspended to the proper curve between towers and also between anchorage and tower; then all the wires that were run in that strand were set to that guide wire. As the strand increased in number of wires, the first wires became guide wires themselves and the succeeding wires were laid to them.

GARDNER L. VAN DUSEN, M. M. E. N. Y.—One question occurs to me in regard to the treatment of the cable. As I remember it, after the wires of the cable were laid in place, they were bound at short intervals and then treated with a petroleum preparation. Was this preparation poured on the cable in sufficient quantity to work through and fill all the space between the several wires that make up the cable, or was the cable immersed in a bath? In some bridges the cable covering is a canvas wrapper. In this instance, I understand, the covering is of Norway steel wound on tightly by machinery. What is the character of the final coating given to this Norway steel wrapper?

ALEXANDER JOHNSON, M. M. E. N. Y.—The wires were protected individually by galvanizing to start with. As the wire was spliced, and before being drawn on the shipping reels at the wire mill, it was run through a bath of petrolatum, a heavy neutral oil, which formed a protective coating in addition to the galvanizing. In the field after the construction of a strand it was coated with petrolatum, and in the following operations of making the core of the cable and compacting the outer strands about this core the entire cable was thoroughly slushed with the oil. In addition to all this the outer wrapping of soft steel wire which is coated with paint furnished additional protection to the cable and its wires.

MARTIN GAY, M. M. E. N. Y.—I remember very pleasantly the excursion which the Society made a while ago across the foot bridges used during cable construction. One of the things learned on that occasion, which has not been mentioned this evening, was the good quality, or the bad quality, depending on the point of view, at all events the lasting quality, of that preservative which had been applied to the cables.

As the cables were about shoulder high above the footways over most of their length, and as, at that height above the water, many of us liked to keep as close as possible to the most substantial thing

in sight, it was inevitable that we should occasionally in a friendly way, rub shoulders with a greased cable. In that way I was able to bring home enough of the preservative to form the basis of some experiments, and as a maintenance engineer, I was pleased to find it insoluble in hot water and soap, in alcohol and in gasoline. It was equally unaffected by whatever solvents were used by the cleaner to whom the coat was sent.

As these reagents were in a much more concentrated form than any which are found in the atmosphere, the strands of the cables, thus protected, will probably endure for centuries.

GEORGE R. FERGUSON, M. M. E. N. Y.—There is one thing that might be added, and that is the utilization of the bridge, as to whether there should be a terminal, or whether the lines of surface cars should be continued across town.

The latter is all very well from the standpoint of the traveling public, but it is going to cut down the number of cars that can be run across the bridge. Take the Brooklyn Bridge at the present time; the cars come to the bridge in three distinct and separate lines, and after those three lines are united, the cars do not stop until after reaching the dividing point on the Manhattan side; in that way about 300 cars per hour can be run. If all the cars were continued across town instead of stopping at the loops, and stops made to let passengers on and off, the traffic would be cut down to about one-third of that of the present time. The fact that the cars on the bridge superstructure are kept at a distance of about 95 ft. apart, and run at a speed of from eight to ten miles per hour, might limit the number of cars more than will be the case on the Manhattan Bridge, where there will be no such limitation as to car spacing; still as the speed depends on the distance the cars are apart, it is doubtful if very many more cars can be run on a single pair of tracks than are run across the Brooklyn Bridge, and in any case the minute the cars stop on a single line, the capacity of the line is reduced to a very considerable extent. A double-track line will carry a large number of trains, provided there are no stops on that line. That is evidenced by the way the Pennsylvania Railroad is building its connection to the new terminal in Manhattan. It has only two tracks, but has stations of considerably more than two tracks. The subway itself is finding that same difficulty in running their express trains. They say, and truly, that if they could run express trains on either side of the platform, they could double the number of trains they are now running, and for that very reason, when it comes to running cars across the Manhattan Bridge, if, when they reach Manhattan, they divide into three lines, going uptown, downtown and across town, a great many cars can be run, but if they are concentrated on the single crosstown lines the

capacity of the bridge itself as a bridge will be cut to a small factor of what it ought to do.

ALEXANDER JOHNSON, M. M. E. N. Y.—I don't know, of course, what will eventually run over the Manhattan Bridge. If all the cars running over the bridge were to come from one direction, unquestionably there would be less operation of cars and trains over the bridge possible than if they come from say three directions. We assume, however, that in all likelihood trains will come—so far as subways are concerned, from three directions. They will come from uptown, they will come from across town, and from downtown through the bridge connecting loop. So far as surface cars are concerned, Brooklyn cars should operate into a loop station at the Manhattan terminal or into a subway. To operate them into the congested condition of street traffic on the Bowery and Canal Street is not desirable.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 56.
PRESENTED APRIL 27TH, 1910.

THE DEVELOPMENT OF JAMAICA BAY INTO A HARBOR FOR NEW YORK CITY.

BY WILLIAM G. FORD,* M. M. E. N. Y.

WITH DISCUSSION BY
ARTHUR S. TUTTLE, NELSON P. LEWIS, PHILIP P. FARLEY, WILLIAM M. BLACK, SIDNEY W. HOAG, JR., AND WILLIAM G. FORD.

The writer may state with little fear of maintainable contradiction that the laws of the growth of great cities are reasonably well defined and that it is recognized that one of the important factors in the achievement of greatness, if not indeed the most important one, is accessibility.

In nearly all cities, excepting such as are primarily the cities of public administration, seats of learning, or resorts for health, the predominating influence is trade—the exchange of commodities.

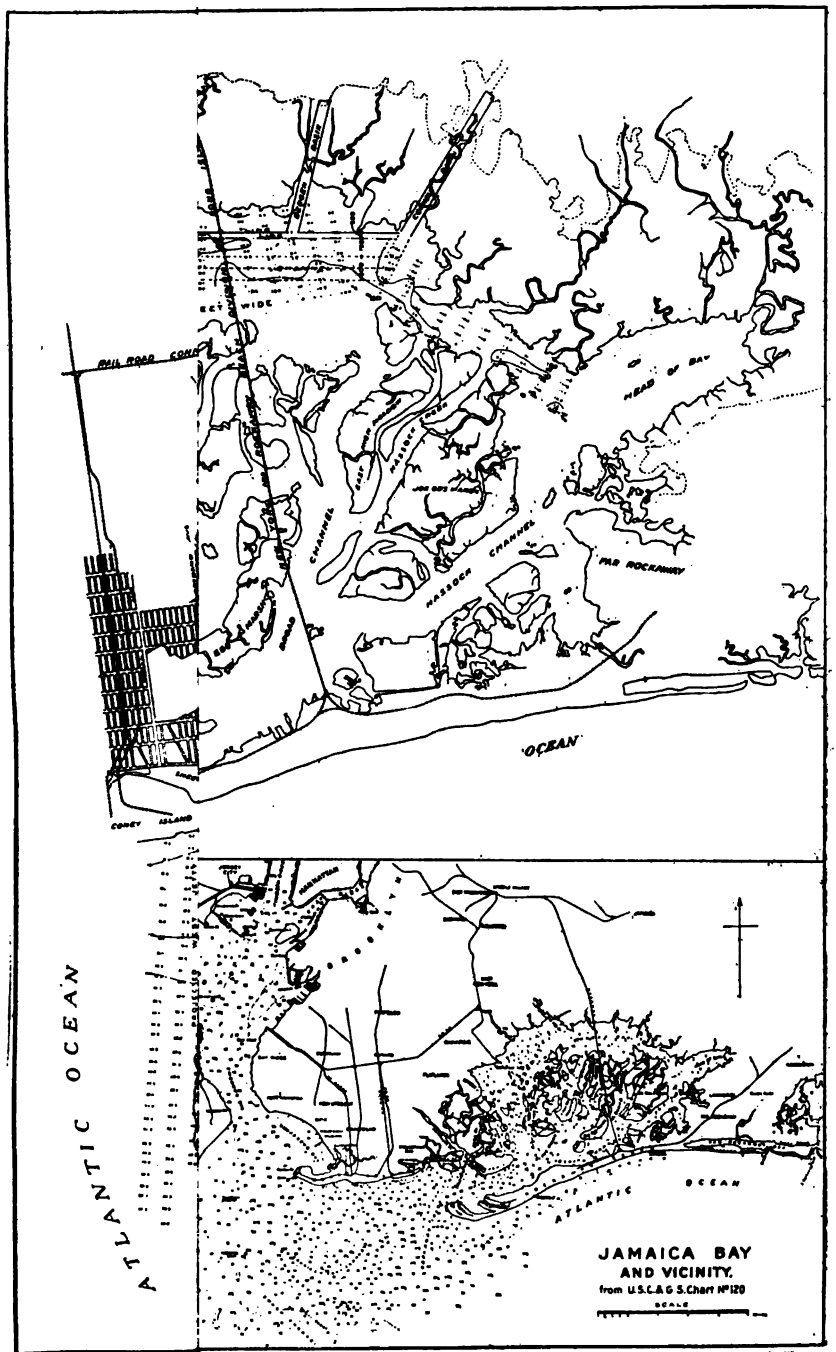
Where this is carried on most effectually come population, wealth and influence.

The greatness of New York is by no means accidental. It is due mainly to the City's relation to the Appalachian range of mountains, the Great Lakes, the Hudson River and the Atlantic Ocean, supplemented by an unusually happy combination of natural topographic and hydrographic conditions.

The writer has no hestitancy in saying that no other harbor in the world combines so many good features, and I know of no other one in which, upon the whole, these advantages have been more ably developed or more conscientiously conserved. I think our Department of Docks and Ferries is subject to hearty congratulations.

* Consulting Engineer and Member of the Jamaica Bay Improvement Commission.

PLATE 19.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.



S OF GENERAL JOHN G. D. KNIGHT, U. S. ENGINEERS.

But even the Department of Docks and Ferries will have reached the limits of its ability to provide proper accommodations for shipping in the not very distant future, unless it is given more space in which to make necessary developments.

It is an unusual coincidence that the principal remaining available water-front, namely, that of Jamaica Bay, is capable of as high, if not higher, degree of development than that already in use, and at a much less cost. In this one instance, at least, the berries at the bottom of the basket are equal to or superior to those at the top. This could never have happened had not (1) the location of this reserve supply of water-frontage been until recently so far away from the centers of activity, in other words, "short" on "accessibility," and (2) had not the magnitude of the work involved, even in its initiation, been so great as to discourage private individuals or corporations, who, through lack of harmony and in the absence of harmonic planning in advance, would have constructed a patchwork irreconcilable with anything really worth while.

The Jamaica Bay project is unique in several particulars, references to which will be made in succession:

One of these is that the City of New York, through its Mayor, upon the suggestion of a former Comptroller, the Hon. E. M. Grout, appointed a board of three Civil Engineers to work out the general details of a plan of improvement. These engineers were also Commissioners. In other words, it was a board of engineers who were expected to act as business men and to produce results as well as plans. In the estimation of the writer this is a field of usefulness in which the engineer may well have a place, and the presentation of the subject will be from the standpoint of the business man as well as of the engineer.

Jamaica Bay is elliptical in shape, its interior is interspersed with islands with a maze of interweaving creeks, while its shores are stretches of salt marshes extending back generally about a mile to the solid upland. The maximum width of the Bay and marshland is five miles, and its length ten miles.

A vessel at sea disappears below the horizon at five miles, and at ten it is difficult to see the smoke from its funnels.

The Jamaica Bay district comprises one-quarter the combined areas of the Boroughs of Brooklyn and Queens.

The Bay is separated from the Ocean by a narrow strip of land, the Rockaway Peninsula, around the western end of which is the entrance channel. The extremity of the peninsula, and consequently the channel, has been traveling westward for very many years at an average rate of something over 200 ft. per annum. The usual depth over the bar is from 10 ft. to 14 ft. at mean low water, and this may be carried around the northerly side of the peninsula for several miles. But nearly all the rest of the mainland is bordered by water less than waist or even knee deep.

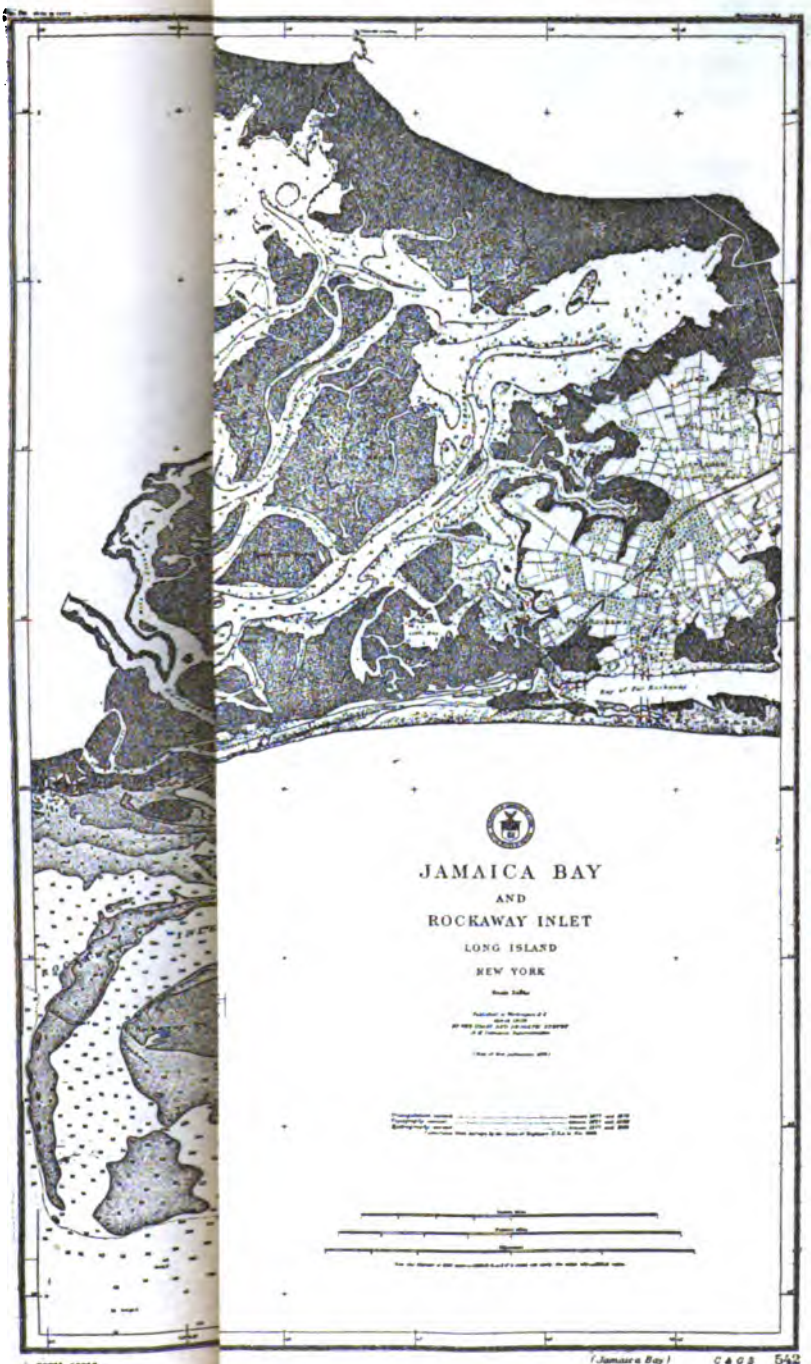
The bottom is generally sand or gravel mixed with a little clay in places. No rock has been found. The surface of the marshes is composed of more or less soft soil and vegetable matter, and generally of slight depth. In very few instances is it necessary to drive a pile to any considerable depth in order to get good holding ground. The material from the bottom may be pumped readily and will make good fill for the marshes. There is plenty of fill available.

The first work of the Commission was to provide itself with topographic and hydrographic data upon which to base studies and investigations. Through the kindness of Mr. O. H. Tittman, Superintendent of the Coast and Geodetic Survey, we were supplied with tracings or prints of whatever useful original topography and hydrography there was on hand, and he had computed for us in advance of other work the triangulation of that part of Greater New York in charge of Mr. A. T. Mosmann, which came within the Jamaica Bay district. We were in this manner enabled to construct polyconic projections, based upon the Clarke Spheroid, scale 1:10 000, plot the triangulation points and transfer as much of the topography and hydrography as desired. From the triangulation points subsidiary stations (generally natural objects) were cut in, and within a very short time, probably within a month or two, there were so many well-developed points available that one's position could be determined, by sextant, rapidly and accurately in any part of this vast territory.

There were some portions of the Bay where the Coast Survey could not furnish us with even reasonably accurate topography of recent date, so that the Commission did some of this by sextant.

The Department of Docks and Ferries gave us the benefit of

PLATE 20.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. FORD ON THE DEVELOPMENT OF JAMAICA BAY.



all the work done by it in the Bay up to that time, and we found that wherever it was possible to compare it with the Government work it checked up splendidly.

The Commission has made current observations and taken soundings of the depth of the soft material of the marshes throughout the Bay.

During the past summer we have completed with care all the topography along the mainland from Barren Island clear up to Queens Borough.

At the end of a little over a year the Commission was able to make a report, but unfortunately it was a divided one, two plans being submitted, differing widely both as to arrangement and as to extent and cost.

Now comes another of the unique features of the project:

It has been the custom of the Federal Government heretofore to make appropriations for the entrance to and channels in a harbor, from time to time, only as the demands of commerce, demonstrated by actual shipping and substantial tonnage, have brought them about. It has very seldom ever made any considerable appropriation for a locality where commerce did not already exist. In Jamaica Bay there was practically no commerce other than that of the local oystermen, coal dealers, &c., and an application for a 20-ft. channel to connect with the Coney Island Channel, a matter of less than one-half million dollars, had recently been reported upon adversely by the District Engineer of the War Department.

Two years thereafter the War Department recommended that Congress go into the enterprise to the extent of about seven and one-half million dollars, and within the past few days Congress has made the necessary appropriation to start the work and provide a channel over the bar and up to Barren Island of sufficient depth and width to permit the entrance of all our coastwise vessels and many of the ocean-going ones.

The total amount spent on New York Harbor by the Federal Government, outside of Jamaica Bay, is less than $10 000 000.

The Jamaica Bay recommendation is a conditional one, and the conditions are such as to be beneficial alike to the country, State and the City. It is a case in which all win.

It came about in this way: Whereas our Federal Government

has entire jurisdiction over and control of our harbors as well as the duty of maintaining them, some of the harbors of the old countries are maintained entirely by the local interests; these doing all the necessary dredging over the bar and in the channels, and even caring for the lighthouses and buoys within their district. In others a middle course is pursued, the federal and local governments working together for the general good. This idea came from the continent of Europe and has been applied here for the first time to any extent through the Jamaica Bay project. The principle is worthy of success and it is earnestly hoped that it may be achieved.

We have a parallel in the State of New York in our so-called "State roads," where the people as a whole pay a part of the expense on account of the general benefit derived, while the county through which it passes pays a part, and the townships more directly benefited pay still another part. Logically our harbor should receive the aid of the city, state and nation.

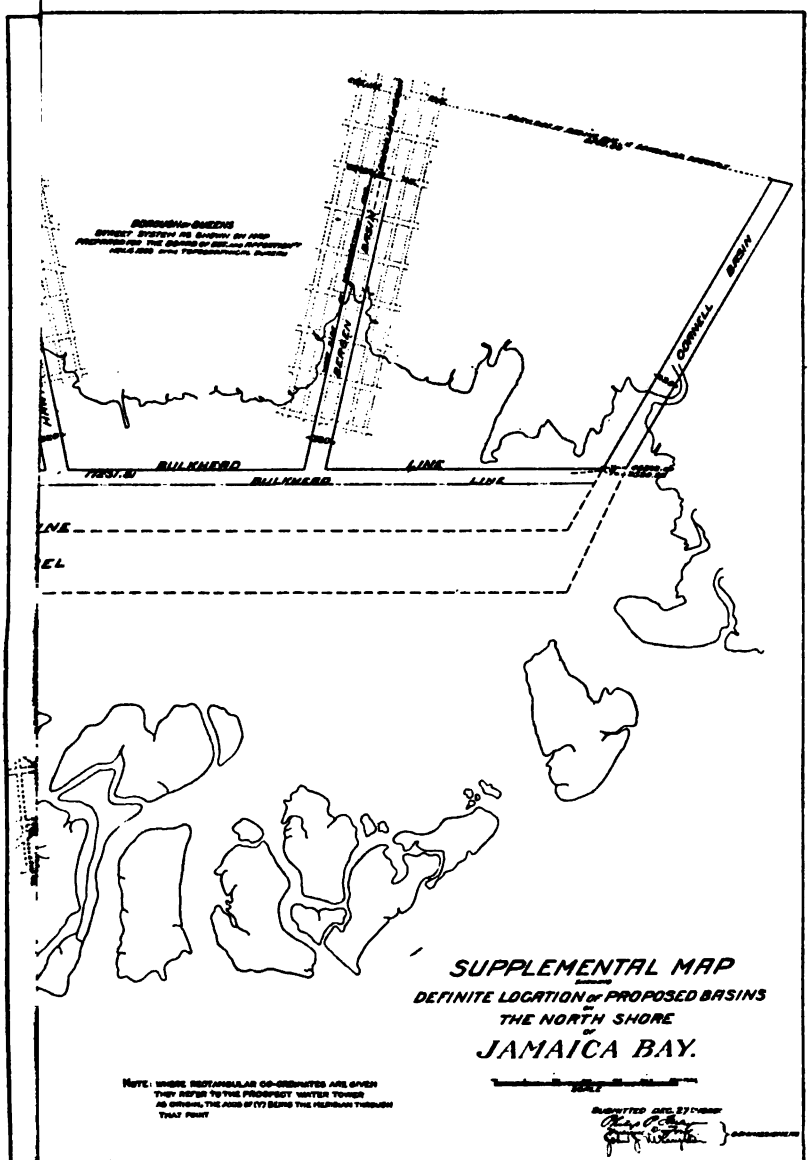
Our Rivers and Harbors Bills have had, unfortunately, rather an unsavory name, that of "Pork Barrels." Should this proposed policy maintain, it is hoped that the bill will be justified in appealing, upon its merits, for a change of name.

Should the member of Congress from "Goose Creek" ask for an appropriation for his constituents, he is going to be very careful as to his recommendations, if he knows in advance that the question will be asked him: "To the extent of how many dollars will the Goose Creekites demonstrate their good faith in the project through co-operation?" Our Rivers and Harbors appropriations, nevertheless, have been too small.

Through the careful and conscientious administration of the Corps of Engineers, U. S. Army, they have been made to go a long way and they have produced, dollar for dollar, more direct benefit than, perhaps, any other expenditure authorized by Congress.

Assuming $400 000 000 annually as the absolutely minimum necessary amount for war and its consequences, it does not seem unreasonable for the country at large to ask for double the usual amount of $25 000 000 for rivers and harbors, and if this prevails, and the Jamaica Bay program were extended, confining the projects to those unquestionably meritorious, the total sum spent through federal and local co-operation would in a very few years

PLATE 21.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.



be of noticeable benefit to the commerce of the country through lessened transportation rates.

Congressman Charles B. Law, member from the district bordering upon Jamaica Bay, secured the insertion of a clause in the River and Harbor Bill of 1907 to the effect that the War Department should confer with certain New York City officials in determining a general plan of improvement for Jamaica Bay; the order of the improvement, its cost and the parts to be borne by the City of New York and the Federal Government, respectively.

Almost immediately after turning in its first report the Jamaica Bay Commission was instructed to enter into conference with the War Department's representative in accordance with the spirit of this River and Harbor Act.

On the last day of 1908 the Jamaica Bay Improvement Commission turned in a plan, agreed upon unanimously, to the senior authority of the City of New York, and on January 30th, 1909, Colonel (now General) John G. D. Knight, U. S. Engineers, turned in the same plan to his senior authority. General Knight in his report advocated the expenditure on the part of the Federal Government of $8 610 500, $5 900 000 of which was for the so-called "main channel."

This latter item had "vicissitudes" of which more later.

The general improvement as now practically agreed upon provides for (1) the creation and maintenance of an entrance channel over the bar and up to the southeasterly end of Barren Island, 1 500 ft. in width and 30 ft. in depth, including the construction, if necessary, of one or two extensive stone jetties—all of this by the War Department directly, and (2) the dredging by the City of New York of a channel 1 000 ft. wide and 30 ft. deep, called the "main channel," joining the 1 500 ft. channel and passing to the northward and eastward, generally parallel to the mainland, some 8½ miles to Cornell's Creek. The War Department proposed that the City be reimbursed for the dredging of the "main channel" at a rate up to but not exceeding 8 cents per cubic yard.

This is another one of the unique features of the project, a creation of General Knight's, providing as it does for a single control over the cut and fill, and doing away in advance with divided responsibility and control through which contractors might readily,

and in entire good faith, come to serious misunderstanding, and possibly controversy.

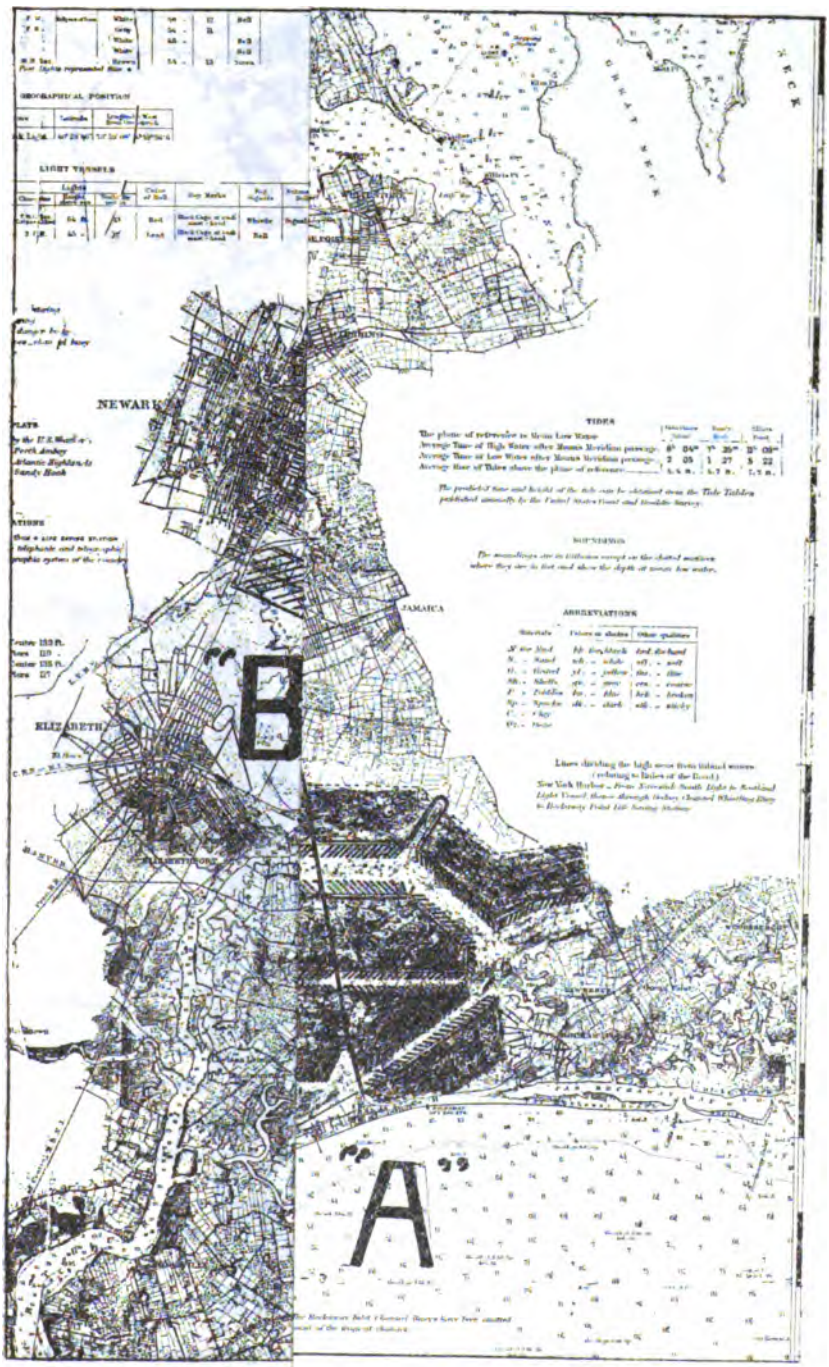
It means that the City of New York must, in some way, acquire the right to fill in the upland or land under water adjacent to the proposed bulkhead, which is to be placed 1 000 ft. inshore of the main channel. It means, also, that it will be "up to" the City to take care of this zone of 1 000 ft. eight miles and more in length, connecting the real shore front with the navigable channel. It means, too, that facilities for the handling of tonnage must be furnished by or through the City, as well as the physical bulkhead skirting the mainland. This will be the part of the work the Government will require of the City. But it will not necessarily be required all at once, any more than the City will expect the Federal Government to do all its part at once. Indeed, it is already understood that both the Federal Government and the City are to initiate the work by the construction throughout of a channel only 18 ft. deep and 500 ft. wide.

The writer referred a little way back to "vicissitudes" in connection with the recommendation for the "main channel." The original recommendation was for $5 900 000. The Board of Review of the War Department was not disposed to pass this and the opinion was prevalent that it proposed to cut it down one-half. An opportunity for a hearing was given the City, however, and His Honor the Mayor sent on a former president of this Society, Mr. Nelson P. Lewis, to plead in our behalf. In a twenty-minute debate he succeeded in winning back $1 750 000—a pretty good business day for a business engineer.

In addition to the main channel, to be made by the City, there are included in the plan five basins of generous width running back some distance from the bulkhead line. It is intended that these basins shall serve for carrying as far inland as they extend, for distribution by truck, coarse freight, such as coal, lime, brick and other heavy materials, reducing to a minimum the land haulage for the interior. The other parts of the basins are intended as feeders for the manufacturing sites immediately adjacent.

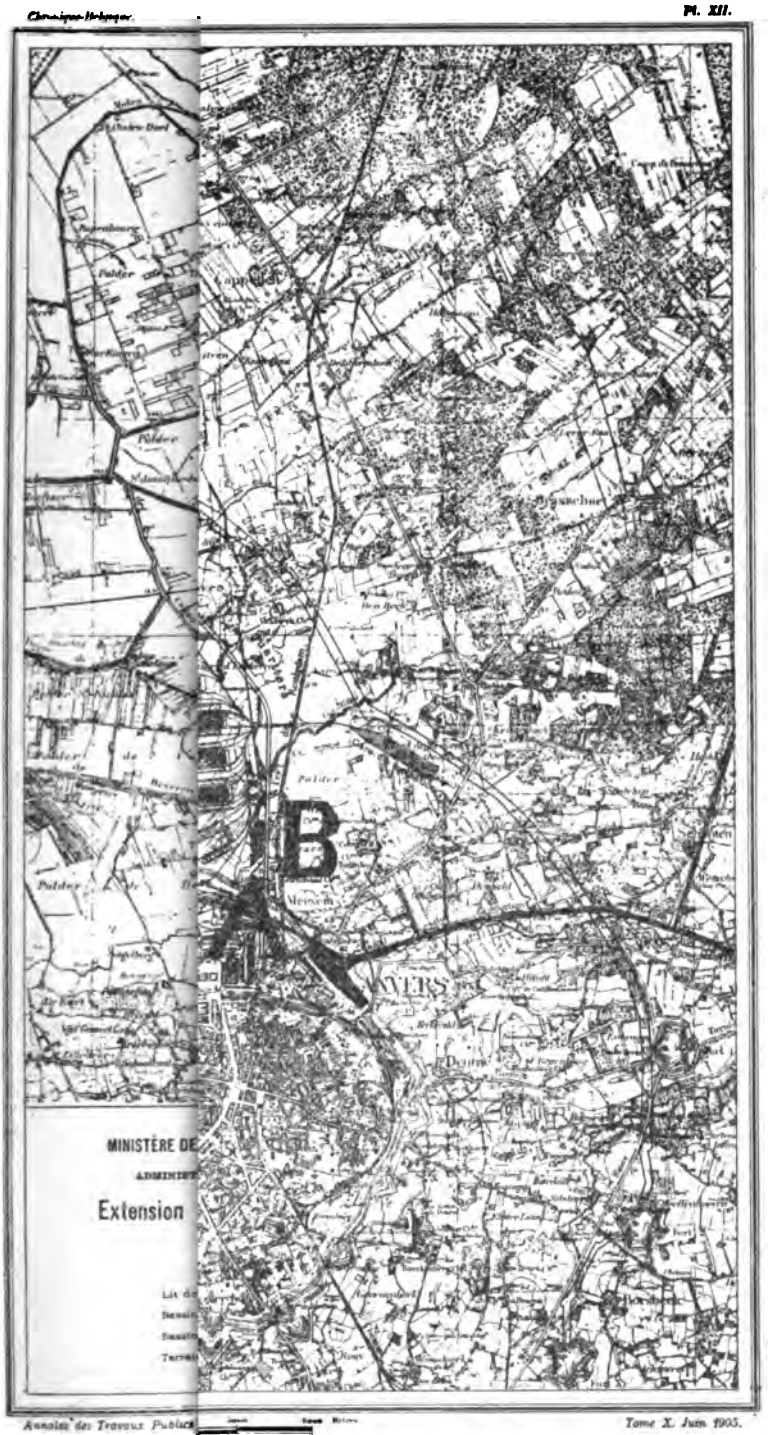
The River and Harbor Act of 1909 contained a clause, inserted through the efforts of Congressman Law, directing the Secretary of War to report whenever he was satisfied that the City of New York

PLATE 23.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. FORD ON THE DEVELOPMENT OF JAMAICA BAY.



T (B).

PLATE 24.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. FORD ON THE DEVELOPMENT OF JAMAICA BAY.



SHOWING RELATIVE LOCATION OF THE PRESENT UNDESIRABLE BEND IN THE RIVER (C).

was ready to do its part of the work. Upon careful investigation it developed that New York might never be ready to do its part of the work. It certainly could not dredge out millions of cubic yards of material from the bottom of the "main channel" unless it had the control of that bottom—that is, ownership.

The Attorney-General of the State claimed ownership by the State, and the State Land Board had made a few grants of land under water to individuals and corporations, under the firm conviction that the ownership was in the State. On the other hand, the Law Department of the City of New York claimed that the title vested in the City.

There was a case involving the issue pending in the lower Court as to the lands under water in Queens. Whatever the outcome in the lower Court, final adjudication might not be had for years. But the point of most concern was that the greater part of the immediate improvement was in Kings County (the Borough of Brooklyn) where the facts were different from those in Queens, and that in Kings no suit at all had been started.

In the meantime, plans were being laid for a campaign for recognition in the River and Harbor Bill of this session of Congress, and it would have been fatal to have had to acknowledge that New York saw no possible way in which to overcome in the near future the dispute as to ownership between the State and the City.

Then came another unique feature of the enterprise: A bill was drafted and introduced in the Legislature on the 3d of April, 1909, about three weeks before the contemplated adjournment. It provided for a settlement of the dispute by the State ceding—as a free gift—all its right and title to the lands under water in Jamaica Bay to the City. The bill was almost dead when introduced, the various committees were soon to go out of commission, and the hurlyburly of the last days was near at hand. The bill was amended several times, it had to be printed seven times. The first reprint was because the printer had mistaken a 3 for a 5 which made the grant include a large part of New Jersey and possibly part of Pennsylvania.

It was amended, perforce, two days before the final adjournment, and as it had to be reprinted and lay on the desks of the members three days, the prospects were discouraging. The printer

generally takes two days, but through good fortune and crowding he was able to get through before midnight that day, and the bill went on the desks a few minutes to twelve. That was constructively one day, and there was yet time.

An appeal to Governor Hughes the next day, however, brought out an emergency message from him in behalf of the bill, and it went through without further opposition, with one day to spare.

The bill itself is not long for what it does, and may be of interest.

"AN ACT

TO GRANT TO THE CITY OF NEW YORK CERTAIN LANDS UNDER WATER IN JAMAICA BAY AND VICINITY.

THE PEOPLE OF THE STATE OF NEW YORK, REPRESENTED IN SENATE AND ASSEMBLY, DO ENACT AS FOLLOWS:

Sec. 1.—To the end that the City of New York may co-operate in the creation of a new harbor in and about Jamaica Bay, including the making of channels, basins, slips and other necessary adjuncts, through the excavation of the soil or lands under water, and otherwise, intended for the advancement of the commerical interests of the City, State and Nation, there is hereby granted for the purposes specified in this act, to the City of New York such right, title and interest as the State of New York may have in and to land under water in Jamaica Bay and Rockaway Inlet and the tributaries thereto which lie to the northward of latitude forty degrees thirty-three minutes north, and to the eastward of longitude seventy-three degrees fifty-six minutes west, as now interpreted, excluding, however, all lands under water included within the boundary of Nassau County. This grant shall become operative upon the United States Government making its first appropriation for the creation of the new harbor mentioned in this act, or upon the City of New York appropriating and setting aside a sum not less than one million dollars for the same purpose."

As soon as the City appropriates $1 000 000 upon which to start the project, the land is ours.

Some of the physical features about the City of Manhattan have necessitated costly seawall construction along the bulkhead line. The average cost of the three types used along the North River is about $365 per running foot.

Under the favorable conditions existing in Jamaica Bay there may be had at the same rate per unit of frontage:

(1) A sufficiently serviceable bulkhead.

PLATE 25.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.

FIG. 1.—SHOWING TYPE OF BARGE USED IN HAMBURG.

FIG. 2.—SHOWING METHOD OF MOORING VESSELS "IN THE STREAM" AT HAMBURG, INSTEAD OF ALONGSIDE A WHARF OR QUAY WALL.

(2) The dredging of the land under water to a depth of 30 ft. for a distance of 2 000 ft. off-shore.

(3) The throwing of these dredgings back of the bulkhead for the reclamation of the lowlands inshore.

It is really fortunate from one standpoint that these inshore lands are low, for if it were not so the cost of creating the channels would be greatly increased.

Through the use of dredgings from channels some 16 000 acres of land may be reclaimed and made many times more valuable, and in the process reduce materially the cost of excavating.

Another unique thing about the Jamaica Bay project is, that owing to the control the City will undoubtedly have over the immediate waterfront a railroad terminal, distribution and transfer system may be had which will be in entire accord with the shipping facilities, will reduce the cost of through rates between the interior and foreign ports to a minimum, and assist the distribution of local freight.

The growth of conditions such as may be found in Manhattan to-day, making prohibitive the direct connection of railroads with some of the shorefront, need not be permitted to prevail here.

It may be assumed that all of the Jamaica Bay frontage along the mainland will not be developed like the Chelsea or South Brooklyn districts, any more than all of Manhattan will be devoted to skyscrapers.

There will be a large area devoted to the storage of bulky materials, and sites for large construction, including those for manufacture, and such development may be made tributary to the carriers on both land and water.

There seems to be little doubt that inadequate terminal facilities and the enormous cost of acquiring property at desirable locations in a city already largely developed has become the bane of railway management. The connecting scheme may be planned here from the beginning for larger scope and greater efficiency than anywhere else in the United States.

The opportunities for railroad terminals are not the only ones. There must be provided in the very near future places for the reception of barges of large size, destined to come from the Great Lakes to the seaboard loaded with various kinds of cargoes for

various destinations. This variety will make a single general terminal impracticable, but for all full cargoes where there will be a transfer to or from ocean-going vessels it will be entirely practicable to have one general terminal provided with facilities particularly applicable to this trade.

Such a terminal could very properly be in prolongation of the axis of the Hudson River. It should be in a locality which will provide the necessary space with least encroachment upon the territory absolutely needed for purely local interests.

It would be fortunate were it also possible to provide in such a locality facilities for transfer of cargoes "in the stream" as practiced so successfully in some of the northwestern harbors of Europe, and at such slight cost.

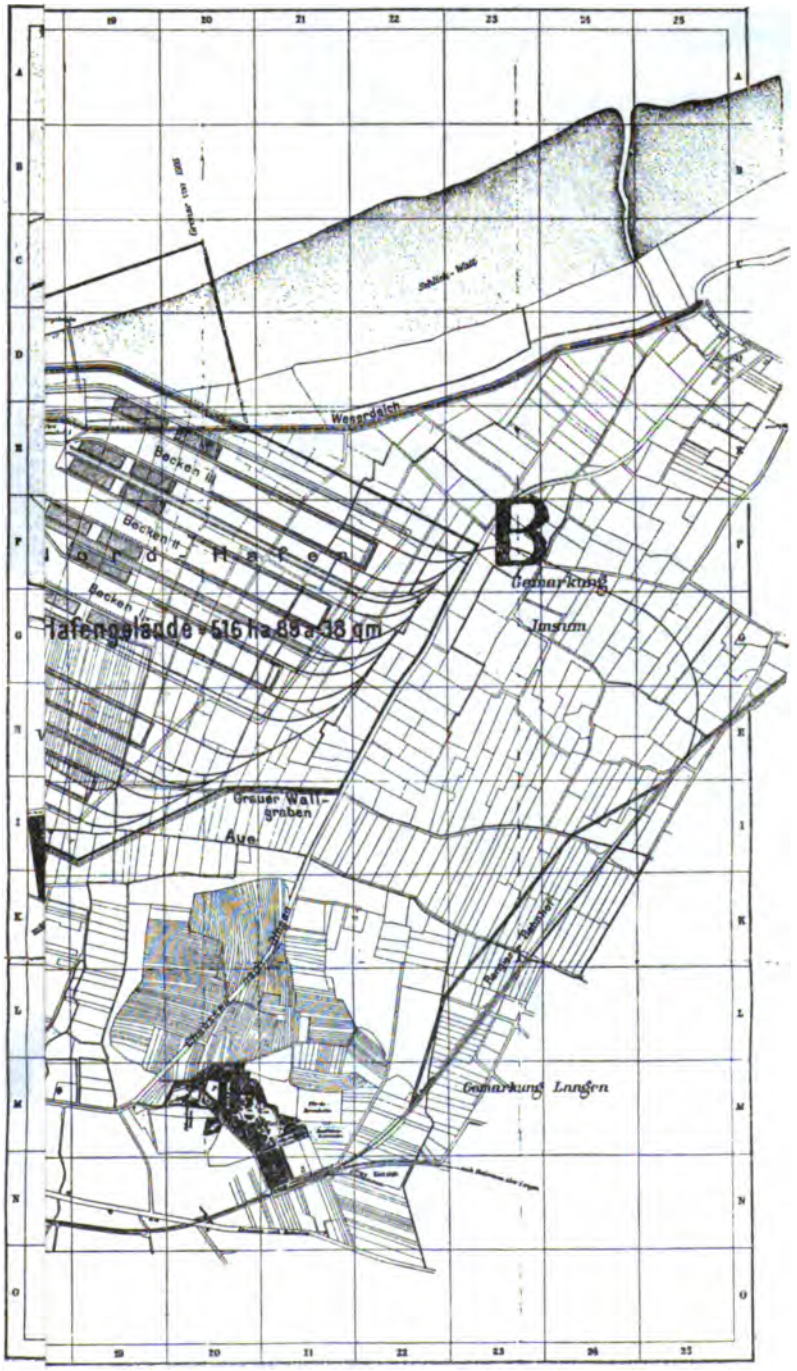
Jamaica Bay is in prolongation of the axis of the Hudson. There are parts of the interior sections, less accessible to the railroad systems upon the more valuable mainland section, which could be very properly and very economically made available for the exchange of through-freight, and there are places where cargoes could be transferred "in the stream," making the port charges so low as to invite and draw trade to our port.

The writer believes that the plan as agreed upon is well adapted to the installation of a diagonal pier system, if started at the beginning of the pier building.

In the writer's opinion there are several distinct advantages in its favor. One very practical one is the convenience and safety with which vessels may be docked. The writer is perhaps more keenly appreciative of these conditions through having been obliged to perform this operation while in charge of vessels.

Were there no currents it would make very little difference as to direction of piers, for there would be plenty of room in which to maneuver, as in such cases a vessel could be brought so as to head approximately in prolongation of the axis of the slip to be entered at some considerable distance away, and the slight necessary corrections could be made with the helm with ease while approaching her berth, but with a more or less swift current the problem is very much more complicated, and any arrangement which permits greater ease in handling should be seriously considered in a new harbor. As an illustration: A man on the bridge of a vessel entering the

PLATE 26.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.



B).

FIG. 1.—SHOWING VESSELS AND BARGES "IN THE STREAM" AT HAMBURG.

FIG. 2.—SHOWING THE USE OF DOLPHINS FOR MOORING VESSELS "IN THE STREAM" AT HAMBURG.

harbor on the ebb, making a landing alongside a structure parallel to the direction of the current has the simplest of all problems, for if he will reduce his speed to one just equal to the adverse current he can, by putting his helm over, make a vessel travel sidewise until it comes gently alongside the landing place. If, however, he has to make a landing at right angles to the ebb current, he has to steer a course at such an angle as to make the vessel's path compensate the amount of drift caused by the current—it is often a difficult operation, and in many cases involves running into structures and creating damage to both wharves and vessels.

It is evident that any angle of pier between that in the direction of the ebb current and a right angle to it would reduce to some extent the difficulties incident to entering the latter with an ebb tide.

Upon the flood tide the practical conditions would be no worse than in the case of a right angle pier because a vessel entering has not been obliged to make so large a turn, and there is less probability of striking the wharf. In going out of the slip, of course, the difficulties are minimized because as soon as the vessel has cleared it has an open space in which to turn around.

There is an additional advantage in the adoption of the diagonal pier system through the possibility of having a longer slip for any given distance between the bulkhead and pier head lines. This will allow the berthing of more than one vessel as now existing on the same side of a wharf, and leaves opportunity to accommodate singly vessels of the reasonably distant future which will have increased in length proportionately to the rate of increase in length of recent years.

Referring to the entrance through the channel: It is interesting to note that the part of the passage between Europe and Manhattan Island in which the masters take the least pleasure is that between the entrance over the Bar and the City itself. The channels leading into Jamaica Bay would be shorter and the time from Europe less. It may also be interesting to note that even in the undeveloped condition of the Bay it is possible to reach it from downtown Manhattan without change of car and for a 5 cent fare in a little over the time it takes to go by a Broadway car from the City Hall to Forty-second Street.

The reduction of a Coast Survey chart, shown on Plate 23, with

the original minority plan superimposed, gives some idea of the extent and location (*A*) of the proposed improvement. It also shows the relative location of a proposed situs (*B*) for a rival development adjacent to Newark, N. J. This latter city has prepared plans, through the study and efforts of a special commission, which will, if carried out, make Newark a port possessing attractive features, and the city has already appropriated the sum of $1 000 000 with which to initiate it.

From observation of various seaports it would appear that trade once gained will continue, provided reasonably good service and port charges are maintained, and it would seem to be most desirable that the City of New York should appropriate at this time an amount at least equal to that already appropriated by her sister (and apparently a future rival) city not only to initiate the work in Jamaica Bay, but to fulfill the conditions imposed in the Sargent bill precedent to the title of land under water passing from the State of New York to the City of New York.

The policy of planning a long way in advance is not as usual a thing in New York as in some of the European cities. The writer has made an inspection of most of the important harbors on that side during the past few years, and the contrast in some instances has been very noticeable.

Plate 24, of Antwerp, shows the contemplated changes there. The port is one of the most important in Europe and yet the area devoted to shipping now, as shown in the middle (*A*), is insignificant compared with that planned for the future shown in the upper part (*B-B*), which includes the creation of a new river, with easy curves, to take the place of the present one, shown on the left (*C*).

While the writer was there the city was adjusting the question of compensation to the individuals for a vast tract of low land opposite the present shipping center, to which it had taken title and possession by some due process of law. It was filling it in, by centrifugal pumping, with the dredging from the bed of the existing river. It may be of interest to note that the slips of the proposed new development are upon the diagonal system.

Rotterdam has the most highly developed barge trade of all cities. Located well up an important river, it is already near the

PLATE 28.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.

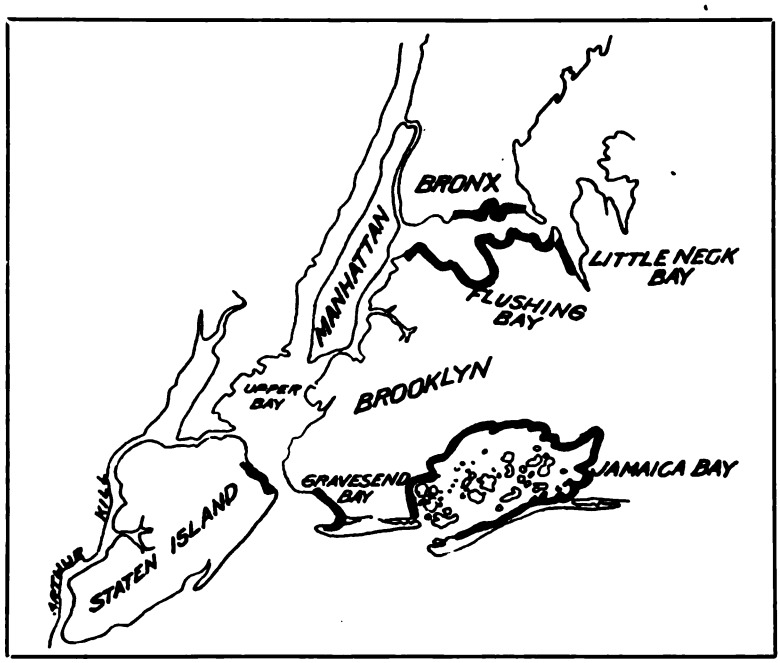


FIG. 1.—HEAVY LINES SHOW UNDEVELOPED SHORE FRONT CAPABLE OF SUPPLYING DEEP-DRAFT WHARFAGE, BUT REQUIRING (IN MOST CASES) EXTENSIVE DREDGING.

FIG. 2.—SHOWING THE MOST HIGHLY DEVELOPED PORTION OF JAMAICA BAY AT THE PRESENT TIME.

PLATE 29.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.

THE BUSH TERMINAL, SOUTH BROOKLYN.

center of an extensive, well-populated area. Generously supplied with natural waterways, some of which have been made more efficient through governmental aid, it has developed a barge of great length and beam and moderate draft, running from 1 000 to 1 500 tons and sometimes, though rarely, as high as 2 000 tons. (See Plate 25, Fig. 1.)

These barges are well constructed and give the very best of protection to their cargoes. The transfer of cargoes between these barges and the sea-going craft is frequently done "in the stream." In other words, the larger vessel does not go to a wharf but moors head and stern in the stream, the barges come alongside and the exchanges take place. This practice gives increased efficiency to the port by setting free just so much wharfage for vessels more dependent upon it, and at the same time reduces the port charges on this class of freight. It makes the port more attractive commercially, and permits the exchange of commodities which would be prohibited under more costly freight rates.

Another illustration of planning far ahead is made apparent in the case of Bremerhaven (see Plate 26), where the new program (*B-B*) exceeds the old one (*A-A*) in area many times.

While it is not intended in many of these instances that the projects shall be rushed to an early completion, it is intended that the general scheme as now laid out shall be lived up to and developed as rapidly as circumstances require.

Hamburg is one of the most progressive and aggressive of modern harbors. The word modern is used here because by far the greater part of the development has been since the early eighties. This city inaugurated a policy of borrowing money at a low rate of interest for dock purposes, putting in the most up-to-date facilities and appliances and renting them for a sum just sufficient to cover this interest, maintenance and sinking fund.

Plate 25, Fig. 2, and Plate 27, taken from Hamburg, illustrate again the efficiency of handling cargo "in the stream."

In the same class of aggressive administration comes Liverpool. The courage with which they have met and overcome disadvantageous natural conditions cannot fail to invoke admiration.

Coping with a tidal range of some 26 ft. is no mean achievement, involving as it does the massive masonry necessary to impound the

vast volumes of water required to float the vessels alongside her points of discharge and the maintenance of a channel across her bar through dredging alone, so that all vessels can enter at all times, proves beyond question her realization of the axiom that the greatness of a commercial city depends upon the attractiveness of her port.

Liverpool has been dredging over 3 000 000 cu. yd. of sand from her bar every year for a good many years past, so that *Lusitanias* may enter without loss of the valuable time gained in crossing the ocean through powerful machinery and liberal expenditure of fuel.

The writer estimates that the total amount of drift of sand about Rockaway Point annually from the east westward, is less than 1 000 000 cu. yd., so that if all of this got into any channel created there, the amount to be excavated would be less than one-third of that which Liverpool handles every year.

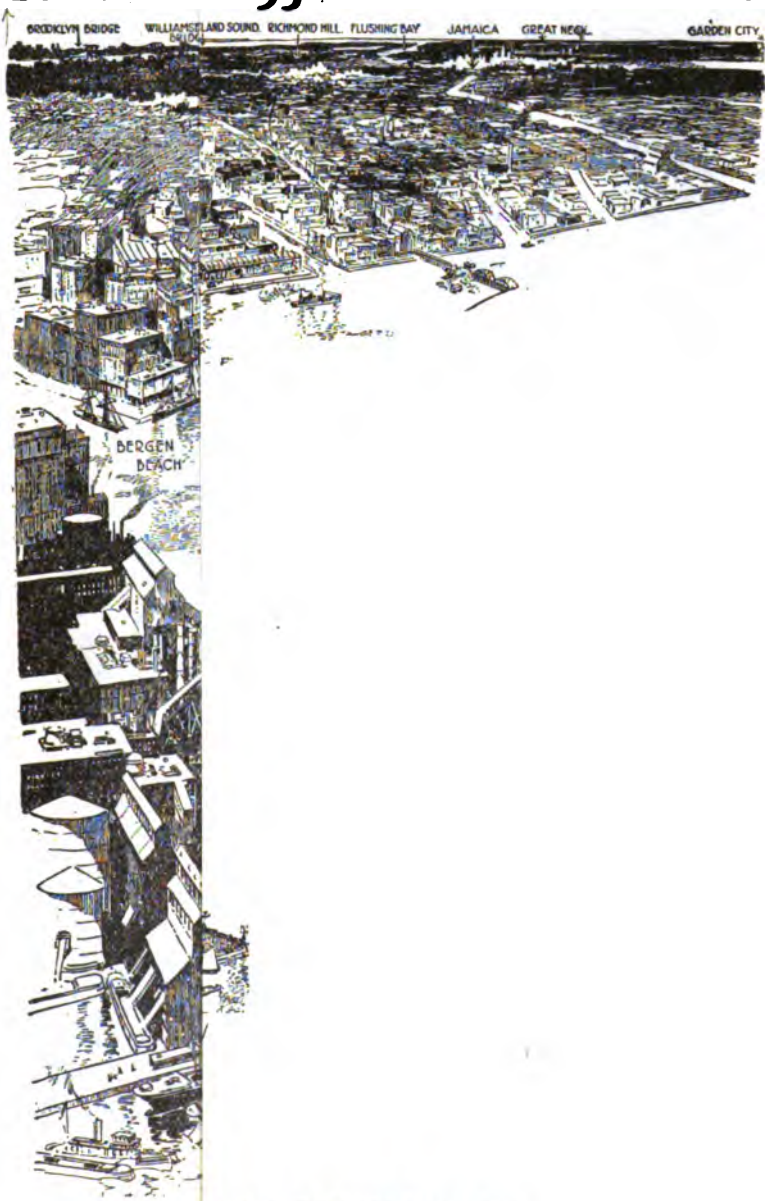
Plate 28, Fig. 1, shows the available remaining undeveloped water-front of New York City.

Some idea of the highest present development of the Bay may be had from Plate 28, Fig. 2. In contrast to this Plate 29 shows what has been done at the Bush Terminal in South Brooklyn, while Plate 30, reproduced with the kind permission of the New York *World,* gives the artist's idea of a future Jamaica Bay, and Plate 31 is reproduced from a print of the Jamaica Bay Improvement Association.

Just how rapidly the Bay will develop, or just how and just when large ocean-going vessels will begin to use it as a new port, it is impossible to say at this time, but there is no question in the mind of the writer that it is destined to be, some day, one of the greatest in the world and that it can be made one of the most efficient.

PLATE 30.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.

To Give 1 Biggest Harbor in the World



s IDEA OF THE FUTURE JAMAICA BAY.

PLATE 31.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
FORD ON THE DEVELOPMENT
OF JAMAICA BAY.

TAKEN FROM A PRINT OF THE JAMAICA BAY IMPROVEMENT ASSOCIATION, A CIVIC BODY WHOSE EFFORTS HAVE DONE MUCH TO ADVANCE THE INTERESTS OF THE PROJECT.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—It has become almost axiomatic that public improvements of magnitude require a long period of public agitation and discussion before assuming tangible shape. In this particular the project which the author has defined is certainly unique as it was only a very few years ago that the Jamaica Bay improvement was conceived and the commission appointed. In this brief time not only the engineering features of the work have been given sufficient study to permit of the formulation of definite lines for the work, but also the State and Federal authorities have been brought into co-operation and public sentiment has been aroused with an enthusiasm so great as to actually insure that construction will not be delayed. It may be possible that this unusual rate of progress was due to a combination of causes, each of which contributed to forward the enterprise or to form a factor in making this period what might be termed the psychological one for advancing it, but I cannot resist the opportunity to suggest that possibly the results may have been due to the fact that the commission charged with the responsibility for the investigation was made up wholly of engineers. In this particular we may also recall the work done by the special commission of engineers which formulated the plan for the new water supply, where skillful and well-directed investigation was not only rapidly accomplished, but also quickly followed by the inauguration of construction. Is there not well-founded ground for predicting that the work done by these two commissions will constitute precedents hereafter to be followed in the conduct of large municipal enterprises? We all recognize that the proposed Jamaica Bay development involves work in which the Federal Government and the Department of Docks and Ferries are primarily concerned, and that at the same time it will involve the solution of important problems relative to the city plan.

I notice that we have present this evening, not only another member of the commission but also representatives of all of the departments interested. The paper is now open to discussion, which, I trust, will bring out a free expression concerning the merits of this project and its details.

NELSON P. LEWIS, M. M. E. N. Y.—Mr. President and Gentlemen.—This plan for the improvement of Jamaica Bay which has been outlined to you this evening is one of the greatest engineering projects of its kind which has been attempted, or, so far as I know, is under consideration. The preliminary engineering investigation has been made, and the beginning of actual construction may be some distance in the future, but that the conception of this project and its promotion is engineering work of a high

order, will not be disputed. It was formerly the almost universal custom in creating a commission to consider an improvement of this kind to appoint laymen, who would employ a staff of engineers to do the field work and prepare the plans. In this instance, however, the Commission was made up exclusively of engineers.

All over the world at the present time there is a revival of intrest in facilities for water transportation. It is somewhat curious that this country should have been so indifferent to this subject during recent years. Possibly this is owing to our remarkable railroad facilities and our relatively cheap railroad rates. To one who has sailed up or down the Rhine and seen the enormous amount of shipping which this river carries, with its constant procession of steamboats and barges, the almost complete absence of shipping on our beautiful Hudson River is difficult to explain. One can look up and down the long stretches between the Highlands and will often see no vessel of any kind in sight. This difference is probably due to the fact that freight on the Rhine is carried largely in barges, which can go long distances into the interior, while on the Hudson River the head of navigation is at the State Dam, at Troy, and the amount of shipping which can go through our present canals without breaking bulk is almost negligible. When the Barge Canal is completed it is extremely probable that we will see a revival of water traffic on the Hudson River, and that this splendid waterway will again come into its own as a navigable stream and will carry a traffic comparable with that on the Rhine and the Elbe.

Other cities besides New York are showing an acute interest in this question at the present time. The Metropolitan Improvement Commission of Boston has devoted much space in its recent report to plans for the improvement of Boston Harbor, and included in this report is an interesting discussion of the subject by Mr. Desmond Fitzgerald. It is proposed to create a new harbor with piers which, if I remember rightly, will have the unprecedented size of 2 000 ft. in length and 500 ft. in width, and it is also suggested that there be created a free port where raw materials can be brought, manufactured and reshipped without interference by the Customs officer. For goods which would go to the interior, this free port would be a sort of bonded warehouse. The Dock Commissioner of this City has given, it is understood, serious consideration to a similar arrangement in the development of Jamaica Bay.

This project is so extensive that it is hard to grasp it in its entirety. It is not something which can be carried out at once, or even during the present generation. If any one living at the present time expects to see the full development of Jamaica Bay, he will be doomed to disappointment. American cities are not in

the habit of looking very far ahead in their plans. Great improvements of this kind are usually undertaken only when they are imperatively needed, and private interests, foreseeing this need, have usually acquired the property needed for such improvements and the City has been obliged to purchase from them at enormous expense, including frequently the destruction of improvements which may have been made.

There was a time when the docks of this City were not only self-sustaining, but very profitable. It is generally conceded that dock improvements, at least along the waterfront of the Borough of Manhattan, are not likely to be profitable in the fututre, even if they are self-sustaining, owing to the enormous value of the property which must be acquired in order to carry them out. In my judgment we have in the proposed Jamaica Bay an improvement which if judiciously handled can be made to pay its own way to a great extent. This, however, will depend upon whether or not the City can acquire the necessary property before it becomes too expensive. Values are constantly being created by the City, and it seems unfair, if not absurd, that the City itself should not have the benefit of these values, instead of allowing the profit to go to the far-sighted and enterprising real estate investor. I do not mean that the City should acquire an enormous amount of land and let it lie idle until the time comes for its improvement as commercial water-front. There are temporary uses to which much of this land could be put, uses which will be of great benefit to the people of New York and which may be profitable to the City itself, and which will at least pay the carrying charges; but it should be understood that the ultimate purpose for the acquisition of this land is the development of this great harbor, and when the time for the actual improvement comes, it should be devoted to this purpose.

As already pointed out by the author of the paper, this is perhaps the first instance in which the Federal, State and Municipal authorities are co-operating in the carrying out of a great improvement, and New York will be under a deep obligation to ex-Comptroller Grout, who first officially proposed this improvement, to the members of the Jamaica Bay Improvement Commission, who have worked out the plans so admirably, and to the State and Federal authorities, both civil and military, who have so cordially co-operated with the City.

PHILIP P. FARLEY, M. M. E. N. Y.—Mr. Chairman and Gentlemen: It is perhaps needless to say that any paper dealing, even though it be remotely, with the improvement and development of Jamaica Bay would prove interesting to me. I regret, however, that the custom does not prevail in this Society, as in the American

Society of Civil Engineers, of sending to the members an outline of the papers prior to their presentation so that they might be prepared to discuss plans for public improvement intelligently, and to the material advantage of the City. Fortunately for me, my connection with the Jamaica Bay Improvement Commission has made me quite familiar with the author's ideas concerning the improvement of the Bay so that I do not feel that the lack of advance information is a serious handicap to a proper discussion. When I learned that a paper on Jamaica Bay was to be presented before you I hoped that it would deal exclusively with that project, that all matter not intimately connected with the improvement would be excluded so that your minds would not be diverted even for an instant from the main issues involved. I hoped further that the improvement would be treated solely from an engineering and economic standpoint since your interest in public improvements must necessarily arise from the fact that you are engineers, and that you are employees of the City of New York.

The thought has frequently occurred to me in the past, and occurs to me again to-night, that I know of no organization or society here or elsewhere that possesses so much latent power for good as that of the Municipal Engineers. I venture to say that properly controlled, its members possess more real power in the matter of public improvements than the Board of Estimate itself, and I venture to say further that no public work of any importance or magnitude can be inaugurated in this City without the consent, approval or advice of at least some engineers who claim membership here. Men who enjoy such privileges as these must of necessity carry equally great obligations.

If such an opportunity, as the reading of this paper presents, is given to you, then you should exercise whatever influence you possess, and should apply your technical knowledge to the advancement of the City's interests, and you should see to it that only such plans are approved as can satisfy most rigid engineering analysis.

Any discussion of this improvement of Jamaica Bay would be futile unless serious consideration is given to three very important questions, namely, the necessity for the improvement, the possibility of making it, and the extent to which the initial improvements should be carried. An engineer should be able to satisfy his own mind, and be prepared to satisfy the minds of other engineers that the improvement is made necessary by existing conditions; he should satisfy his own mind, and be prepared to satisfy the minds of other engineers that it is possible to make and maintain such an improvement, and finally he should be able to show that conditions are such as to offer at least strong hopes of a reasonable

return being made upon immediate expenditures. Time will not permit an extended discussion upon these various heads, but a few words in connection with each may not be out of place.

In a minority report submitted to the Board of Estimate and Apportionment by the author of this paper in December last an attempt was made to show the necessity of the improvement of Jamaica Bay in three different ways, and it is interesting to observe the difference in the results obtained. The first method, and the one that appealed most to the mind of the speaker, was by adopting the method used by the Advisory Board of Engineers employed by the City of Newark in 1908. The same method was employed by the Dutch engineers retained to report and prepare plans for the harbor of Valparaiso, and was likewise used by the majority members of the Jamaica Bay Improvement Commission in connection with their work on the Bay. It consists of establishing the relation existing between population and foreign tonnage, and between tonnage and wharfage required. The result of the application of this idea in the case of New York, as found by the author, showed that the additional wharfage length required in the City in the year 1950 would be about 80 000 lin. ft. The ten new piers in South Brooklyn are each able to provide about 3 000 ft. of wharfage, or 30 000 ft. in all, equal to three-eighths of the total required in the estimate. With the northeast shore of Staten Island still to be developed; with the head of the Newtown Creek capable of furnishing additional wharfage; with the Brooklyn Basin, and its 50 acres of water surface still untouched, and with the additional length that can be afforded by renovations along the Manhattan shore, it is apparent that the computed increase demanded can be procured without entering Jamaica Bay at all except for local or coastwise business.

The second method adopted by the author was to compute the probable increase of foreign tonnage by the year 1950, which he placed at 38 000 000 tons, and to assume that the foreign tonnage constituted but 10% of the total tonnage of the Port. Translated into a different form of expression this would mean that the increased business of the Port of New York in the next 40 years would amount to 380 000 000 tons, and would require an additional wharfage length of 250 000 ft. for foreign business or of 2 500 000 lin. ft., or nearly 500 miles for the entire business of the Port, thus requiring construction to be provided at the rate of 12 miles per year for the next 40 years. Naturally no such rate of growth could be even thought of, and so the third method was employed as giving figures more nearly approaching the amount required to justify the necessity of improving Jamaica Bay.

The third method was to take the figures compiled by the Depart-

contours on this line is about 2 000 ft., with the interior contour receding at the rate of over 200 ft. per year. It may be well to call attention to another fact that will eventually have a bearing upon the question, namely, that Rockaway Point has advanced so far to the west already that it has caused changes in the interior of the bay which threaten to be serious. Twice or three times the ebb tides in rounding the corner of Barren Island in endeavoring to make the inlet have undermined the corner, the last time seriously threatening the buildings of the Sanitary Utilization Company on the island. This fact has led some engineers of note to believe that the proper place for the entrance channel to Jamaica Bay is through Rockaway Beach at a point just opposite the east end of Barren Island. This would require controlling works inside and outside, and would be quite costly, but may eventually prove to be the best solution of the problem of making a permanent, self-sustaining channel. It may be asked why should City engineers concern themselves with a problem that belongs to the engineers of the Federal Government. It is true that the problem is one, the solution of which rests in the hands of the Federal Engineers, but it is likewise true that whatever money the City spends in connection with this improvement is well or ill spent in precise ratio to the success attending the efforts to maintain the inlet.

The foregoing facts, taken in conjunction with the present actual needs of the Bay, should guide us in fixing the initial expenditure, sufficient, I am sure, to warrant us in proceeding with this improvement with care and caution. Our original commitments should be sufficient only to provide means of supplying building materials and supplies to the local communities and to enable the Government to study the effects of its earlier works.

One other small matter and I have finished. It has to do with the interior of the Bay and its treatment. Colonel Knight in reporting upon this matter said: "It is suggested that the secondary channels through the islands in the center of the Bay, should radiate from the entrance of the Bay," and in another place in his report remarks that "the maintenance of the capacity of this basin necessary to secure a maximum tidal scour through the entrance is all-important in the absence of an appreciable fresh-water discharge." In this connection I desire to remark that the tidal prism of Jamaica Bay in the treatment of the islands given in the majority report of 1907 is reduced 17% from the present amount, while in the minority plan of that date, shown you to-night, the loss is 47 per cent.

Another feature is interesting. The length of the main channel from Barren Island to Cornell's Creek is 45 000 ft. By building piers 1 000 ft. long the wharfage obtained is 180 000 lin. ft. This

added to the amount available in the basins, or 75 000 ft., makes a total available wharfage of over 250 000 lin. ft. If we allow 150 tons per ft. per year, an amount shown to be conservative, we have a capacity of 37 500 000 freight tons, and as the net registered tonnage in the Port of New York is nearly twice this amount, the latter tonnage amounts to 75 000 000, or 15 000 000 tons more than the entire foreign business of the ports of the United States. This represents the business it is possible to do along the west and north shores alone. How many years before such an immense amount of water-front will be in use in Jamaica Bay it is impossible to estimate. Yet it is proposed by some to buy at once all the meadow land as far as Cornell's Creek, to dredge as fast as possible a channel all the way to the same place and to hold the central islands for commercial purposes when, for at least 100 years, they might be doing a useful service as a pleasure ground for the people, or as a place for the installation of public institutions. It is my opinion, furthermore, that if a certain portion of these central islands were taken and developed and leased for long terms as villa sites the return would be sufficient in all probability to satisfy, in a large measure, the expense attached to making the commercial development along the west and north shores. These leases could be made for 50 or 100 years, and, upon their expiration, need not be renewed if any particular portion of the lands seemed to be demanded for commercial purposes.

In conclusion let me say that all the facts, so far as my investigations have gone, seem to justify conservatism and caution, and I hope that those among you who cherish the highest ideal of the engineer, which is to secure the biggest material return for the least expenditure of money, will not fail to reflect upon this problem so that you can with confidence advise and counsel those upon whom will rest the burden and responsibility of appropriating moneys for this improvement.

WILLIAM M. BLACK.*—This Jamaica Bay Improvement is one of very far-reaching importance. The whole subject has been presented to you very ably and in an interesting manner this evening by the author and also has been presented in two very able reports gotten out by the Commission, largely the work also of Mr. Ford. They contain a great deal of matter which is well worth consideration, but I think for the present the matter most deserving consideration is that presented to you by Mr. Lewis. New York has been growing very rapidly, and any one who is familiar with its growth and with the engineering features connected with its growth, will know that, as has been stated here this evening, it is only

* Colonel, Corps of Engineers, U. S. Army.

too true that in almost all cases city improvement work has been planned for immediate necessities and not for the future, so that to-day we find in the East River a narrow, congested stream, covered with traffic so thick that in the many foggy days found here it is dangerous, whereas fifty or maybe a hundred years ago there were ample areas along the east shore of Manhattan Island which were marsh or covered with tide water, and which should have been partly reserved for the needs of future commerce. The same condition we have on the North River. Mr. Lewis spoke of the difficulty of getting the Chelsea Improvement. That difficulty did not exist a few years ago. You all know the difficulty now of getting a terminal street and proper facilities for handling freight. Mr. Tomkins himself has very recently invited attention to it, and it is going to be a matter of great expense to the City of New York to provide proper facilities for the freight coming here. Similarly up in The Bronx we have a little stream bearing a large tonnage, and it is perfectly absurd to think that the width of that channel is 60 ft. when the navigation in it is by boats of 30-ft. beam or of over 30 ft., so that to permit the passage of a barge through, the vessels lying at wharves along the banks have to be moved.

These things arise from the fact that in the past the future was rarely considered to any very great extent. New York will have to grow. It may be a matter of judgment, and it certainly is a matter in dispute, just how soon the necessities of New York will require the extensive use of Jamaica Bay, but there is no question about it that to-day the shores of Jamaica Bay can be obtained, the nucleus of the improvement made and the streets and the wharf system laid out in such a manner that as the need for the growth and development comes, the improvements necessary can be made at a minimum expense; and, what is more, I believe it can be done with actual financial profit to New York City.

A short time ago I had occasion to make a few calculations on a little piece of sand down in that immediate vicinity. To-day it is washed by the sea. It is extremely unstable; you cannot build anything on it at all. We found, to make it absolutely safe for all building construction purposes, to make it a place that could be used for any commercial or business or residential purpose, would require an outlay at the outside of $400 000, and that the value of the land so reclaimed, at the price now being paid for lots in the immediate vicinity, would be between $5,000 000 and $7 000 000. There is no reason in the world why New York City should not take advantage of this; should not reclaim these marshes in its vicinity around Jamaica Bay sufficiently to admit of city improvements, and, when development comes, dispose of them with

profit to itself and to the community. The undertaking is too large for any one person, or even for a group of persons. It is properly a City undertaking. And it is by no means an unusual thing for the City and the United States to co-operate in these matters. New York City did it a short time ago in the improvement of the Harlem River. It first bought the land for making what is termed "The Harlem Ship Canal," gave it to the United States, and the United States then went on with the improvement. A few years ago Philadelphia did the same thing. Baltimore did it a few years earlier. Down in Florida, a comparatively poor community, the City of Jacksonville in the late 80's, or the beginning of 1890, found that its annual commerce was about $600 000 a year. It was a small town; I think they had about 30 000 or 40 000 inhabitants, and yet that community raised bonds and spent several hundred thousand dollars on the improvement of the St. Johns River, in connection with the improvement made by the general Government, since the Congress was unwilling to appropriate quite as rapidly as desired, and the result has been that to-day the commerce of Jacksonville is reckoned in the millions instead of in the hundreds of thousands of dollars. I think the commerce has increased something like 10 to 20 fold, largely as a result of this far-sighted action on the part of the City of Jacksonville, and yet there were many who doubted the expediency of the expenditure, exactly the same way as in New York to-day people are making light of this necessary improvement in Jamaica Bay.

Mr. Farley has spoken of a number of engineering difficulties in regard to holding that channel. Mr. Farley possibly does not know that at Charleston, as late as 1889, they had great difficulty in obtaining a depth of 15 ft. To-day they are getting 30 ft. and are contemplating a greater depth. At the mouth of the St. Johns, when I was there, we thought we were extremely fortunate when we got 11 ft. over the bar. There is now 24 ft. and the people are calling for 30. In both those cases the bar was far more exposed and far wider than that at Rockaway Inlet. The distance between deep water inside and outside the bar was much greater than is the case in Jamaica Bay. There are many details of the work required to secure the channel which will have to be more carefully studied out. The studies are only preliminary, as far as made. It is intended now, as I understand it, to make simply a channel 18 ft. in depth and 500 ft. in width. That is only for a starter. That will enable the City, under the project that it seems about to adopt, to bulkhead along the shore front as defined by a bulkhead line, to acquire the land behind this imaginary line, which to-day is of little value, to start the field work and begin the undertaking, and also will give a channel large enough for the large

amount of local traffic now needed, in building materials particularly, for a section which is very rapidly growing. As that improvement progresses, it will be a very simple matter and a very easy matter to secure the greater width and depth of the entrance channel on the lines which experience will show to be the best. I, personally, have no doubt whatever of the possibility of carrying into effect the whole improvement of Jamaica Bay as contemplated now by the City of New York.

The necessity for maintaining the tidal prism, mentioned by Mr. Farley, undoubtedly exists.

Gentlemen, I think—I will repeat it again—that in all of this municipal work in New York it is the duty of all of us engineers, whether of the National Government, of the State Government, or of the City Government, to look to the future and to plan our works in such a way that our successors will not have to destroy our work before creating the new improvements required by the City's growth.

SIDNEY W. HOAG, JR., M. M. E. N. Y.—Mr. Chairman: I do not know that I can add anything to what has already been said by the gentlemen who have preceded me, as the ground seems to have been pretty well covered in a preliminary way. Individually, I am an optimist for the future of Jamaica Bay. I take my cue from two things: One is the embarrassment of the past, or the environments of past experience, and the other is the opportunity for a remedy which is presented right there at Jamaica Bay, a condition which makes it possible for an improvement of the nature contemplated to be carried to a very successful issue, and this cue is the availability offered for direct railroad connection, we might say unbroken railroad communication, with the Pacific coast. This possibility exists nowhere else in the Port of New York within City limits affecting a municipal water-front. Manhattan Island, we all understand perfectly well, is no longer available for unbroken rail communication with the main trunk lines excepting the New York Central.

In relation to the *ultimate success* of such a vast enterprise as is contemplated, when considered as an entirety, while I am inclined to pin my faith to the judgment of the Government experts, I must say that I have an intuition that makes me endorse the sentiments hinted at by Mr. Farley. The present location of the entrance to the Bay seems, from the meagre study I have been able to give it up to the present time, to be setting up a dynamic action at the westerly end of the Bay injurious or destructive to the easterly end of Barren Island; that the scour alluded to by Mr. Farley is progressing is a matter of fact, and this leads me to ask any member of the Commission why the Commission adopted a

bulkhead line extending from the easterly end of Barren Island to Canarsie in the precise location occupied by the established line. What was the particular combination of features, either existing or anticipated, that suggested this particular location? The southerly end of the line established lies in 90 ft. of water. Imagine building a bulkhead on that line, not to question the practicability of maintaining such a bulkhead. Now, if this dynamic action is created by the present location of the entrance to the Bay, it seems to me to indicate a necessity for making one of two alternative radical changes in the scheme as now laid out. I anticipate that ultimately the particular bulkhead line alluded to will have to be shifted to the westward or else a change in the entrance to the Bay will have to be considered. Again, I have an intuition that the latter will be inevitable. The maintenance of an adequate entrance at the present location is fraught with such far-reaching results by virtue of the constructions essential for such maintenance that it is by no means certain that the Ambrose Channel will not become involved. The possibilities at Jamaica Bay are so great that any attempt to limit or restrict its use to barge or inland traffic—which is all that can be accomplished by the present entrance—could not be justified by any expected increase in the volume of business in one hundred years. I mean by this that in so far as the grand scheme of improvement of Jamaica Bay is concerned, it must be considered as an auxiliary harbor to the Port of New York, and not as a mere *basin* for barge and inland traffic. Ultimately, I do not see why by a proper structural treatment in the matter of artificial entrance, ocean steamers should not enter Jamaica Bay, but I apprehend that up to the present time no sufficient study of this important feature has been made, for, again, such an artificial entrance must set up forces that will show their effect considerably to the eastward. This feature of the Jamaica Bay improvement is beyond all question the most interesting, as it will require close and careful study of the present forces as well as the forces that will be created by the extent and direction of any resistance barriers, such as will be necessary for the maintenance of an entrance.

I want to say one or two words about diagonal piers. The impression might be created by the paper before the Society that diagonal piers are unknown in this port. Diagonal piers are not a new proposition at all in Manhattan. You will find diagonal piers on the water-front extending from Fifty-ninth Street to Seventy-second Street on the North River. Abstractly, it goes without saying that diagonal piers headed towards the direction of traffic afford slips that are the very easiest for entrance and exit, and are practical and desirable in connection with a scheme that

involves a wholesale condemnation of property such as at Jamaica Bay, but the question may arise in the minds of many: If diagonal piers are so desirable, why have they not been more extensively used in the Port of New York? The answer to this question explains the whole philosophy of diagonal piers, and I will say right here that if a revenue-producing water-front like that in Manhattan is to be the aim, diagonal piers become very limited in scope. The City, as a rule, owned the land under water extending out-shore from the foot of streets while the land under water covered by slips was in private ownership, but the tide water that floats the vessels is public water, and a vessel can be brought to and moored to a pier built at the foot of a street on City property, and not invade private property. If diagonal piers had been built, they would have intersected private property, and all those portions of a pier excepting what came within the zones in extension of streets, would have required condemnation of private property, and the pier system of New York would not only have cost infinitely more that it has, but the advance of water-front improvement would have been retarded 50%. At the Chelsea Section where all of the property was condemned, diagonal piers were considered, but the limited stretch—half a mile in length—of the section rendered every available foot in demand for wharfage, and the environment of that locality created by Gansevoort Market at the south end and the Ferry Terminals at the north end, would have made it possible to have built but eight piers instead of nine.

The tidal current, however, is the principal determinant, as the effect of the ebb tide,. for instance, on a large transatlantic liner leaving the southerly side of a pier, stern foremost, on the North River is the principal obstacle to contend with. It can readily be conceived how a large steamship, operating under these conditions, would sweep and command an area which would practically cripple all other traffic and create a more or less dangerous condition during such a maneuver as the vessel must perform before it can be pulled or pushed around with the aid of tugs and its own steam in order to point its bow southward.

The only possible excuse for diagonal piers under such conditions as these is the impossibility of obtaining piers of adequate length by the usual method of straight-out piers. There are, therefore, many important considerations not apparent on the face of a proposition that operate, or should operate, as controlling features in an important water-front development.

The essential details connected with the physical improvement of Jamaica Bay are a little bit in their infancy as no very serious study has yet been given by the Dock Department to such details, but the main features of that Department's operations are, as recommended

by the Commissioner in his report to the Mayor, in accordance with the report of the Jamaica Bay Commission.

I do not know that there is anything else that I can say on the subject just at the present time, because we have not yet taken up as a department the matter of actual construction.

WILLIAM G. FORD, M. M. E. N. Y.—Mr. Chairman: Just to answer the inquiry, while it is before us, that Mr. Hoag made about that bulkhead line, I would say that the great depth of water has come since the bulkhead line was established.

As regards the diagonal pier system, I am very glad to have such an able advocate of it as Mr. Hoag, because I know it will bring about a great deal of good. It is very evident that under the conditions existing in Manhattan years ago, where they only had the right to build directly in front of streets, it was often impracticable to build diagonal piers. A more fortunate condition will exist in Jamaica Bay, where the City will own all the land and have no worry as to adjoining owners.

The author feels that if Mr. Farley quotes him at all he should do so correctly, and that he should not attribute by inference deductions the author has never made.

Mr. Farley's quotations of what the author said in his minority report of last December are inaccurate, and in one instance, particularly, through the changing of the word "wharfage" into "tonnage," with subsequent deductions, gives an impression totally different from that in the original text.

Mr. Farley says: "The second method adopted by the author was to compute the probable increase of foreign tonnage by the year 1950 which he placed at 38 000 000 tons, and to assume that the foreign *tonnage* constituted but 10% of the total *tonnage* of the port. Translated into a different form of expression this would mean that the *increased business* of the Port of New York in the next 40 years would amount to 380 000 000 tons," etc.

This would be ridiculous, and the author has never had any such thought. What the author did say (p. 117) was that "the *wharfage* in New York for foreign trade alone does not exceed ten per cent. of the *water-front*," which is true, and he concluded this part of his report by saying:

"The development of Jamaica Bay will not begin with the introduction of Chelsea piers, nor Hudson Terminal buildings. On the contrary, it will start in all probability with accommodations in keeping with an 18-ft. channel at mean low water. It will be a distributing point for all kinds of materials needed in the building up of the adjacent interior territory; it will furnish the sites for industrial enterprises, including those for the manufacture of commodities where the raw material and finished product may have

an opportunity for transportation by water and rail alike; it will supply, in addition to wharfage, spaces where for the time being at any rate, large areas will be required.

"As time goes on the development will be on a higher commercial plane, and it may be that some day some of the first enterprises will have to give way to strictly commercial projects. However this may be, however uncertain the details of the future progress may be, or how impossible it may be to predict with any degree of certainty, the wharfage required by 1950, we may rest assured that it will be a wise thing to allow plenty of room now, and to plan with a wide enough margin to permit, if possible, the installation of the things most desirable in the practice of that time."

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ECONOMIC ASPECTS OF CITY PLANNING.

BY BENJAMIN C. MARSH.*

WITH DISCUSSION BY
ARTHUR S. TUTTLE, NELSON P. LEWIS, CALVIN TOMKINS, KENNETH ALLEN, GILBERT ELLIOTT, ROBERT R. CROWELL, AND BENJAMIN C. MARSH.

It would be entirely inappropriate for me, neither an engineer nor an architect, to attempt to state in detail just the way by which a city plan should be made. I fear that I am presumptuous even in attempting to state what the economist and social worker would have accomplished by that somewhat indefinite term "City Planning." To clear the way, therefore, for a discussion of the subject I submit the following definition: "City Planning" is the orderly development of a city by which each section is arranged for the purpose for which it is best and most economically adapted, so that a harmonious entity is secured. This development must be for the common good and not for the individual's gain.

To secure this harmonious entity in American cities it is fundamental that we should have a wider extension and application of the police powers of the State under which are, of course, subsumed the health powers, the taxing powers and analagous methods by which the State controls the ambitions or cupidity of its individual members, when such ambitions or cupidity are in conflict with that greatest good of the greatest number which it is the primary function of government in its several capacities to secure.

* Secretary, Committee on Congestion of Population in New York City.

A brief review of the development of the idea of city planning in this country and abroad will serve to emphasize the distinction between the connotation of the term here and there. Here it has been chiefly, though not exclusively, æsthetic and outward; abroad it has been more fundamental, utilitarian and economic.

The grouping of the public buildings, as in Cleveland and St. Louis, the broadening of overladen thoroughfares and the provision of vistas or a system of parkways have been the dominant characteristics of our American city planning until within a very few years. There has not been any co-ordinate conception of, nor emphasis upon the right of city governments to regulate the initiative and control the greed of citizens in the construction of private buildings or buildings used for quasi-public purposes such as offices, depots and factories. In foreign countries, however, notably Germany, Austria, France, Switzerland, and recently England, the opposite side has been dominant, and while the artistic side of city growth and development has found fuller exemplification than in our own country, the starting point of city planning has been the health and efficiency of the individual family and the citizen.

The right of even the poorest family to a healthy home has been the starting point or the central objective of city planning, especially in Germany and Switzerland, and is the crux of the recent "Town Planning Bill" in England. The location of factories, the development of docks and means of carrying both passengers and freight have been determined in relation to the prime purpose of improving the homes of the working and professional classes of the city. With our apparently inexhaustible flood of immigration, we have not had the incentive nor compulsion to conserve the health, vitality and efficiency of our industrial and professional armies, which have been a most potent inducement in continental countries, where in addition a military army has demanded the highest grade of soldiers and of mothers to bear and rear soldiers.

We may enumerate the following features of a comprehensive city plan:

1st. Proper housing of the city's masses for a reasonable proportion of a fair wage, and within easy access of their work.

2d. Direct and adequate roads connecting the main business centers of a city with smaller roads of such width and construction

FIG. 1.—COMMON GAME GROUND AND PERSONALLY CARED FOR GARDENS.

FIG. 2.—RELIEVING MANHATTAN'S CONGESTION. AT QUEENS TERMINAL OF THE QUEENSBOROUGH BRIDGE.

as not to impose an unnecessary and burdensome cost upon the occupants of small houses.

3d. A proper system of water supply and sewage disposal pipes and wires.

4th. The economic location of factories and the prohibition of factories in districts where they will be an injury to the neighborhood, and, as a necessary corollary, the provision of means for carrying freight.

5th. The elimination of the cost of carfare, as far as possible, to the working population.

6th. The decentralization of the city's business, pleasure and educational interests.

7th. The provision of adequate parks, playgrounds and open spaces, with space for public buildings to furnish not merely sites but settings.

8th. Such control over the location and volume of buildings for manufacturing and office purposes as will enable the city authorities to anticipate and provide adequate means of carrying passengers.

9th. The control of the development of new and unbuilt sections of a city, and the incorporation of adjacent areas so that their development may similarly be controlled.

We take up these features in order.

1st. Proper housing of the city's masses for a reasonable proportion of a fair wage and within easy access of their work.

Admittedly this seems to involve two questions, or determinations: (*a*) What is proper housing for the city's masses, and (*b*) What is a fair proportion of a reasonable wage for rent? (See Plate 32, Fig. 1.)

We are fortunately turning some attention now to the problem of proper housing as distinguished from proper warehousing of a workingman's family and the distinction is of great importance to the city planner. Upon the definition of proper housing will depend to some extent the rate of wages which labor unions and other organizations seeking to secure and maintain a good standard of living will adopt as fair wages. In this connection we must note that the principles of city planning are pretty generally applicable, and that we do not and must not think in terms of the development of Manhattan, The Bronx, and Brooklyn. (See Plate 32, Fig. 2.)

The standard for the English workers is pretty clearly indicated in the "Town Planning Bill," to which reference has been made, under the terms of which a city may determine the number of cottages that may be constructed per acre, and, even more, the number of rooms and volume or cubage as well as floor space of each cottage, and also the garden area for each one. Ordinarily the cottages or houses are expected to be 14 to an acre with a maximum of 20. (See Plate 33, Fig. 2.) It is the intention to have these rent for from one-fifth to a maximum of one-fourth of the average workman's wages. Manifestly such a standard is impossible for most sections of Greater New York, but it is possible to restrict tenements so as to have not over thirty families to a net acre and by so doing to give each family an opportunity to have at least a small garden, and at a rental ot $10 to $14 a month. The cost of land for this must not, however, exceed 40 cents a square foot ready for building, with roads, sewers and sidewalks constructed. (See Plate 33, Fig. 1.) The nature of the roads will, of course, be largely determined by the character of the district. Assuming that we attempt to restrict the number of families to thirty to a net acre, each family house of four or five rooms to have a separate entrance and an individual yard, should the street frontage be wide or narrow? In districts where it is desired to furnish homes of this character for rentals of $10 to $14 a month it is extremely important that the frontage be the minimum possible to save the tenant the cost not only of construction, but also of maintenance of roadway, and this same necessity of keeping down the rent dictates that since sewer and water connections must be made with the mains in the street the garden in front of the house should be shallow. With a width of 17 ft., 30 lots, on a block 510 ft. between corner buildings, can be secured having a depth of 86 ft., which is ample depth to give a small garden in front so as to permit the widening of the street subsequently at a minimum expense and still afford a large enough garden in which to raise a good assortment of vegetables. (See Plate 35.)

In one of the first-class cities of the State a large real estate owner is improving 1 000 lots 40 by 120 ft. with four, five and six-room single houses which will rent for from $12 to $16 per family. Fortunately, however, his land is worth only about 10 cents per

PLATE 33.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.

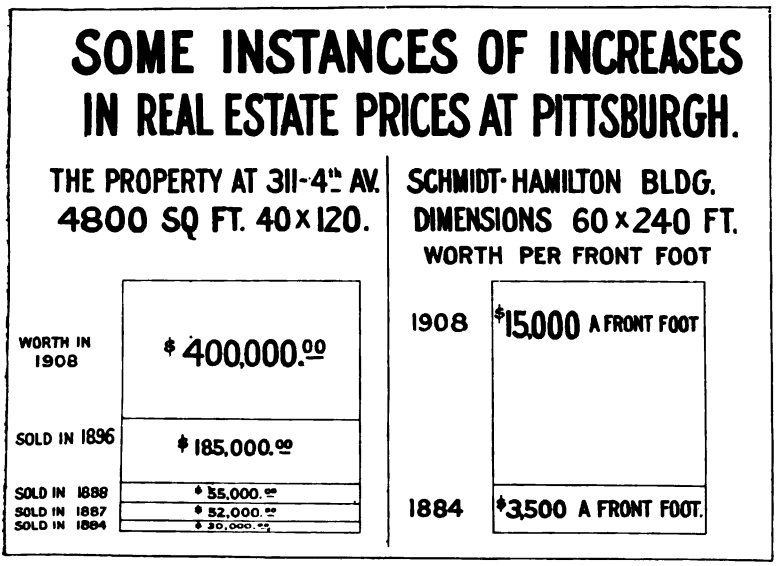


FIG. 1.

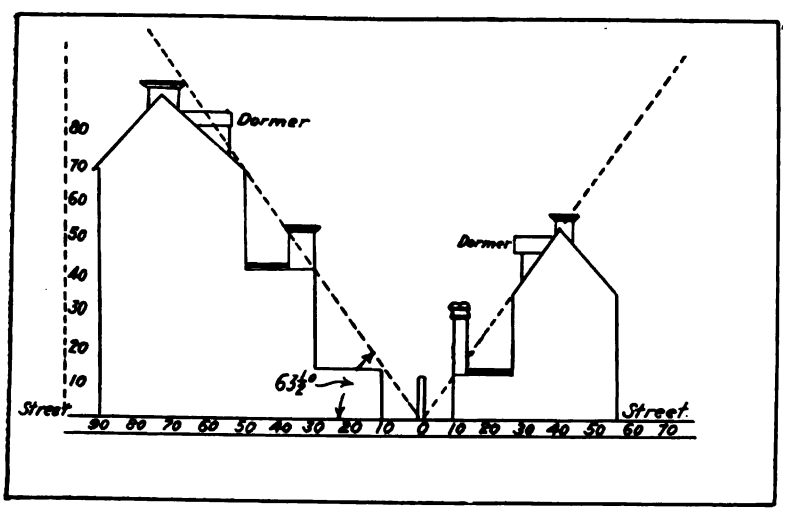


FIG. 2.—LONDON'S METHOD OF SECURING ADEQUATE SUNLIGHT.

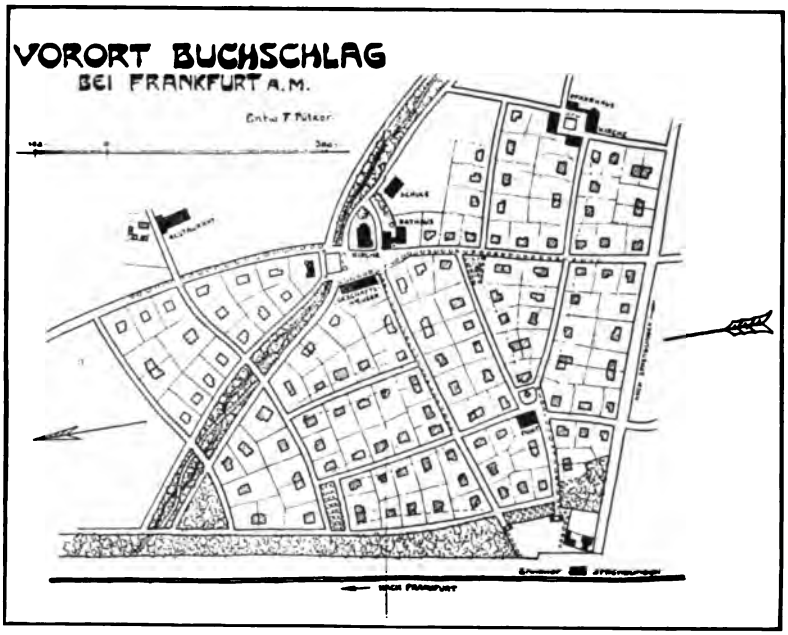


FIG. 1.—SUBURB OF FRANKFORT-ON-THE-MAIN, SHOWING THE DETACHED METHOD OF HOUSING FOR WAGE-EARNERS, WITH A GARDEN FOR EACH HOUSE.

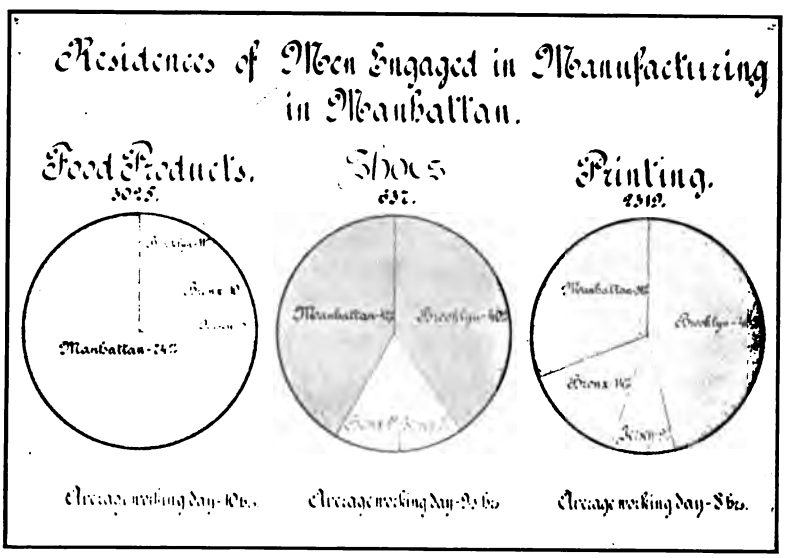


FIG. 2.

square foot, while some of the houses are rather ornately designed, but intended for Germans and Italians. Economy in construction of houses can also be effected of course by having closed buildings only two rooms deep around a general open space with open fences to protect each garden or space.

One of the most interesting experiments in the planning of such districts is Hampstead Heath on the borders of the City of London and within twenty minutes' ride by the tube of Charing Cross. This model suburb comprises 320 acres, 80 vested in the London County Council and 240 in the Hampstead Garden Suburb Trust, Limited. Not more than an average of eight houses to the acre is permitted, but they are of various sizes and rent with gardens, to which is devoted over half of each plot, for from $144 to $240 a year. (See Plate 34, Fig. 1.) That this plan involves a departure from the system in New York City is no more patent than the necessity for this departure from New York City's development to date.

The Lex Adickes of Frankfort-on-the-Main is an interesting illustration of the exercise of the police power on behalf of economic development of a district or tract of land. Under the terms of this law, when over half of the owners of over half of the land which is badly subdivided petition the municipal authorities the land may be compulsorily thrown into a common tract and then redistricted or replotted, the original owner being assigned as nearly as possible lots in the same location after the lots have been arranged to afford suitable sites for building and 30% of the area dedicated to the city for streets. (See Plate 36.)

The value of the land redistricted must be at least equal to that taken or the city must make good the difference. This rearrangement may also be done at the instance of the city authorities. Compare this procedure with that fine flower of democracy known as "House Planting," of which we have had so many conspicious illustrations in New York City.

A plan is now being developed to house 1 000 families in single houses of four rooms and a bath with large gardens for each family for a rental of $14 to $15 per month within walking distance of Manhattan across the Queensboro Bridge. Such accommodations

should be furnished within a short distance in Queens for $12 a month at the maximum. (See Plate 37.)

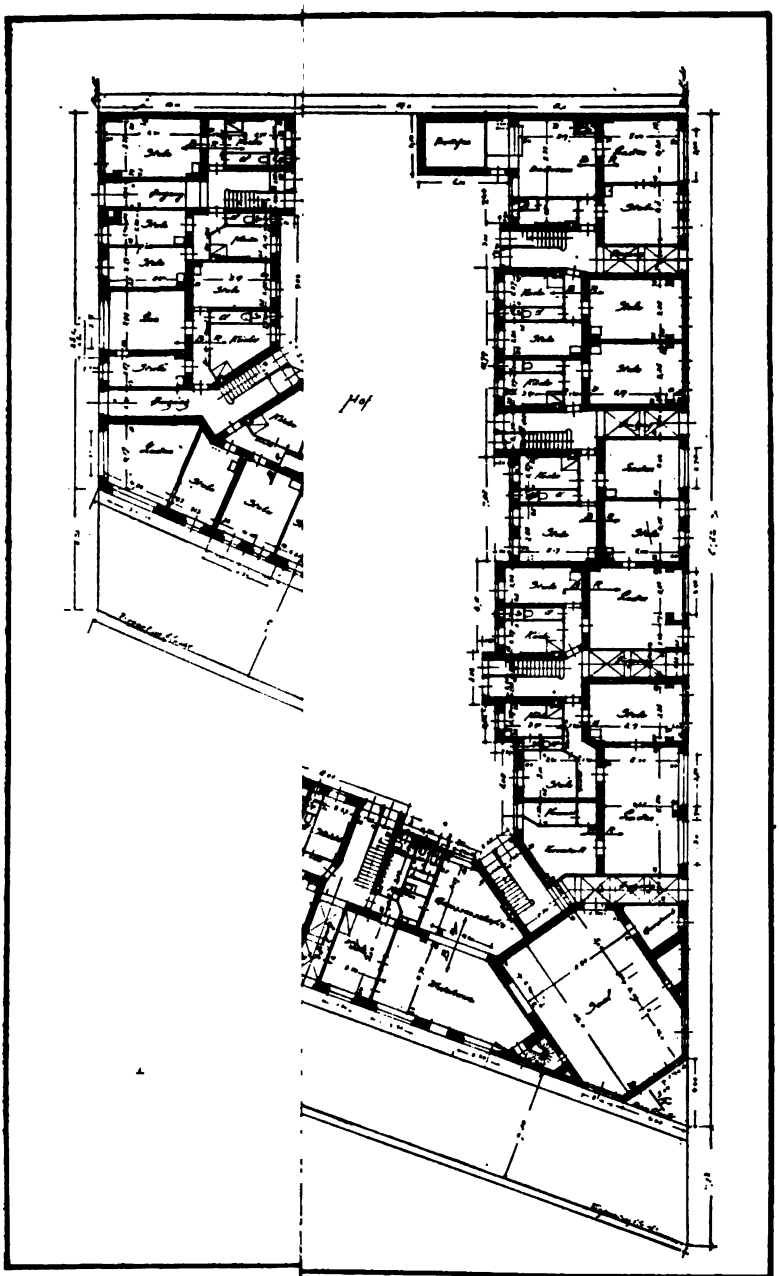
2d. Direct and adequate roads connecting the main business centers of a city with smaller roads of such width and construction as not to impose an unnecessary and burdensome cost upon the occupants of small houses.

Professor Stubben, one of the most practical students of City Planning in the world, observes regarding roads and the general relation to a city plan:

"Success in town planning is more likely to be attained by seeking out the natural topographical conditions. A full consideration for the levels, roads and boundaries must be the basis upon which all schemes must rest, and these considerations can only be left out of account if they become antagonistic to the legitimate requirements of traffic and town extension, or for economic or æsthetic reasons. The closer a town plan adheres to the natural conditions, the more original and attractive it will be. The filling in of the secondary roads to the main network and thoroughfares should be approximately rectangular, because the rectangular is the most convenient form of building block, and for the actual traffic requirement the diagonal system can always be resorted to. The radial form of arrangement is advisable for important focal points, town gateways, railway stations, the approaches to bridges and similar situations. Curved streets adapt themselves as a rule better to hilly ground than straight ones; for wide vistas, distant perspectives, and grand monumental effects the straight line asserts itself. The day has gone by for the unqualified employment of definite systems; henceforth they should not play a ruling but a subsidiary rôle."

The width of various thoroughfares in prominent cities is indicative of the requirements. The width of Avenue des Champs Elysées, Paris, is 230 ft.; Unter den Linden, Berlin, 190 ft.; Ringstrasse, Vienna, 185; Whitehall, 120-145; Holborn Viaduct, 90; Broadway, 70 to about 100 ft., while we have few avenues in New York over 100 ft. wide. It seems disloyal to revert in this connection to our own failures, but it is in fact only loyalty to the possibilities and necessities of the future to mention that we seem to have inverted the usual procedure of civilized countries and to have adopted the rule "the narrower the street the higher the building," as illustrated by the buildings on Exchange Place, Nassau

PLATE 35.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.



TENEMENTS ARE NECESSARY IF IN EVERY ROOM BY HAVING THE BUILDING ONLY

Street, and that labyrinth of passageways designated the Wall Street section. (See Plate 38.)

The first feature in most city planning has been the determination of the main streets or primary arteries of traffic. When these have been determined the other or minor streets can be planned and constructed with reference to the needs of the locality.

The London Traffic Commission suggest in their report that new or widened streets should be divided into five classes:

Main Avenues	140 ft.
First-class Arterial	100 "
Second-class Streets	80 "
Third-class Streets	60 "
Fourth-class Streets	40-50 "

This difference in width of streets is an important factor in keeping down rents and it is entirely feasible to construct roads only 15 to 24 ft. wide provided space is left on either side for subsequent widening. "In a street planted with trees," says Mr. H. Inigo Triggs, in his volume on City Planning, "the width should be not less than 70 ft., and in this case a good proportion would be 17 ft. to each footway and 36 ft. to the road. If it is desired to introduce trees in streets narrower than 70 ft., they might be planted on one side only, preferably the sunny side, or in the middle of the street."

Traffic requirements naturally demand that all streets should be as flat as possible. The law in Germany limits gradient of public streets to 1 in 50, and it is suggested that whenever practicable in secondary streets of any length, a grade of 1 in 40 should be aimed at. The French Administration des Ponts et Chaussées admits the limit of 1 in 33, for the inclination of a route royal, and 1 in 20, for a chemin vicinal de grande communication.

Importance should also be attached to the direction of streets. We have been accustomed to so much hideousness in our streets that we do not realize the possibility of having streets as well as houses, that are restful. One of our charitable societies is organizing expeditions to introduce children to the parks. Not only by providing parks generously and generally, but by proper arrangements of streets we can do much to make such an introduction unnecessary. Streets should be so arranged that the maximum view

and variation may be secured from each house. Mr. Triggs makes a strong plea from illustration of the value of curved streets instead of the formal regularity which enables one to judge in anticipation just what will smite his eye when he rounds a corner. Sweeps like Regent Street, the Thames Embankment from Westminster Bridge, the Arno Embankment at Pisa, and the Ring Strasses of many German cities and Riverside Drive are not necessarily more expensive, but vastly more harmonious and restful than the Puritanical austerity of Fifth Avenue in front of the Library to be, or the tremendous stretches of some of our speedways and public drives.

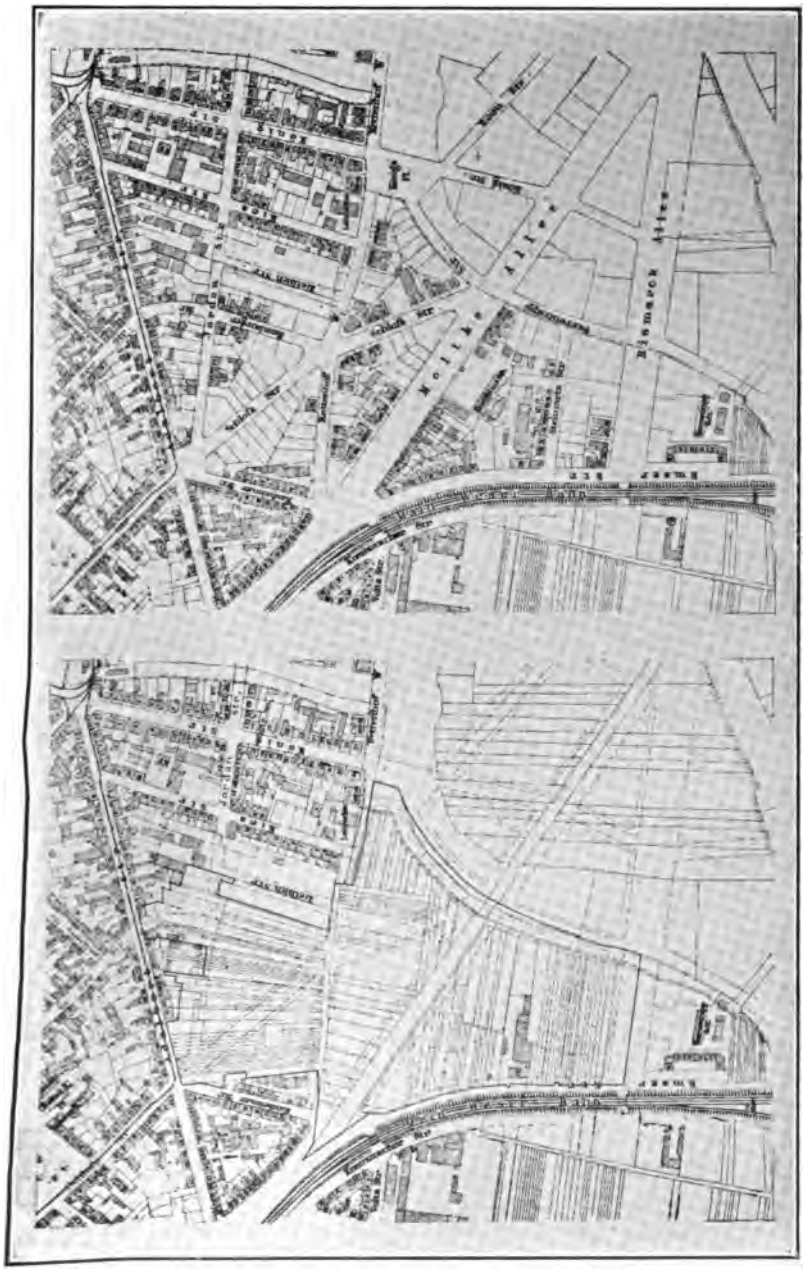
The aim of the city planner should be not merely to furnish a few æstehtic stores in the way of development, but "to brain out," if I may coin the term, the artistic possibilities of every factor of the city plan and part of the city and furnish it at the minimum cost available to the man and woman who must toil, who will respond to the beautiful near home, but who will be deprived of any opportunity to respond to the beautiful if inaccessible. Art must literally be domesticated and not merely be imported or visited as one visits a shrine on a pilgrimage.

The limits of time preclude any lengthy discussion of how greater service may be secured from streets or how congestion of streets may be avoided, but we cannot forbear referring to Mr. Halsey Ricardo's suggestion that on narrow streets, when the expense of widening would be practically prohibitive, the first story should be set back and the higher stories, if necessary, slightly projected. I would suggest, too, that in view of the general possibility of utilizing vaults under the present sidewalks, the city might compromise in giving the use of this city property to the owners of abutting property in return for their giving the use of part of their ground floor to the city. We can readily see, for instance, what a saving this would mean in Fifth Avenue, Nassau Street, and some of the crosstown streets.

3d. A proper system of water supply and sewage disposal pipes and wires.

The need for providing adequate sewer systems would be superfluous for me to dwell upon when you all know of the damage suits the city has had to pay for flooded homes, that there is a

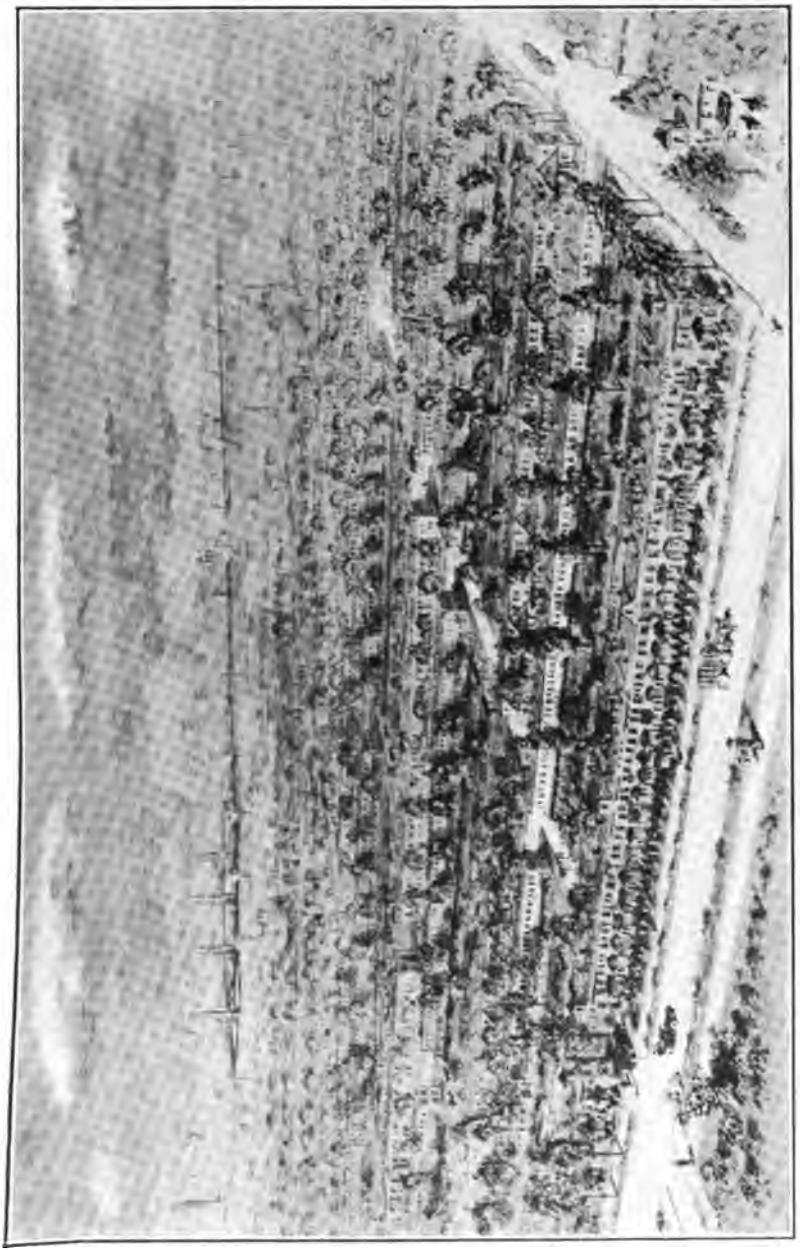
PLATE 36.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.



BEFORE REPLOTTING. AFTER REPLOTTING.

ILLUSTRATION OF THE OPERATION OF THE LEX ADIKES IN FRANKFORT-ON-THE-MAIN, SHOWING THE UNECONOMIC SUBDIVISION EXISTING BEFORE THE REPLOTTING, AND THE ADVANTAGEOUS LOTS PROVIDED BY THE REPLOTTING.

PLATE 37.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.



STEINWAY PARK.

district of 30 000 inhabitants in the city with hardly a sewer, and our propensity to turn our rivers—the bathing places of the city—into open sewers. So, too, when we have to guess where pipes are under our streets, and when we realize that there were seven years of open streets below Chambers Street for repairs to substructures in one brief year, we admit that "City Planning" involves a departure from the primitive methods of prospecting for gold to get to the pipes in our overburdened streets.

4th. The economic location of factories and the prohibition of factories in districts where they will be an injury to the neighborhood, and, as a necessary corollary, the provision of means for carrying freight.

Economy in production has been sufficiently emphasized in successful corporations, but the historian of civilization in the 19th and 20th centuries will probably ask why New York, the seat of several universities with chairs of economics, the proud possessor of a Chamber of Commerce, and a Merchants' Association, as well as a Taxpayers' Association wherever two or three citizens are gathered together in economy's name, should have adopted a system of manufacturing on the principle of that famous king who "With twice ten thousand men, marched up a hill and then marched down again." This has been and is our method of manufacturing. Every additional handling of freight means an additional cost, which, as Mr. Brisbane has recently informed us in the inspired editorial columns of the *Vox Populi, "Somebody has got to pay."* A prominent manufacturer has estimated that the cost to the citizens of wear and tear upon the streets due to the needless handling of freight back and forth is at least $30 000 000 a year. (See Plate 39.)

We have permitted the construction of our great factories right in the midst of our congested island of Manhattan. In 1906, *one-twelfth* of all the workers in factories of the Greater City were located in the old Sixth Assembly district in *one-eleven-hundredth* of the city's area, and this patch of land almost equidistant from both rivers, on which they should have been located. Consider the river frontage; 93 out of 99 of the buildings on the Hudson River Piers from the Battery to 134th Street are two stories or less in height, while even on the opposite side of the marginal street about half of the buildings are three stories or less high. (See Plate 34,

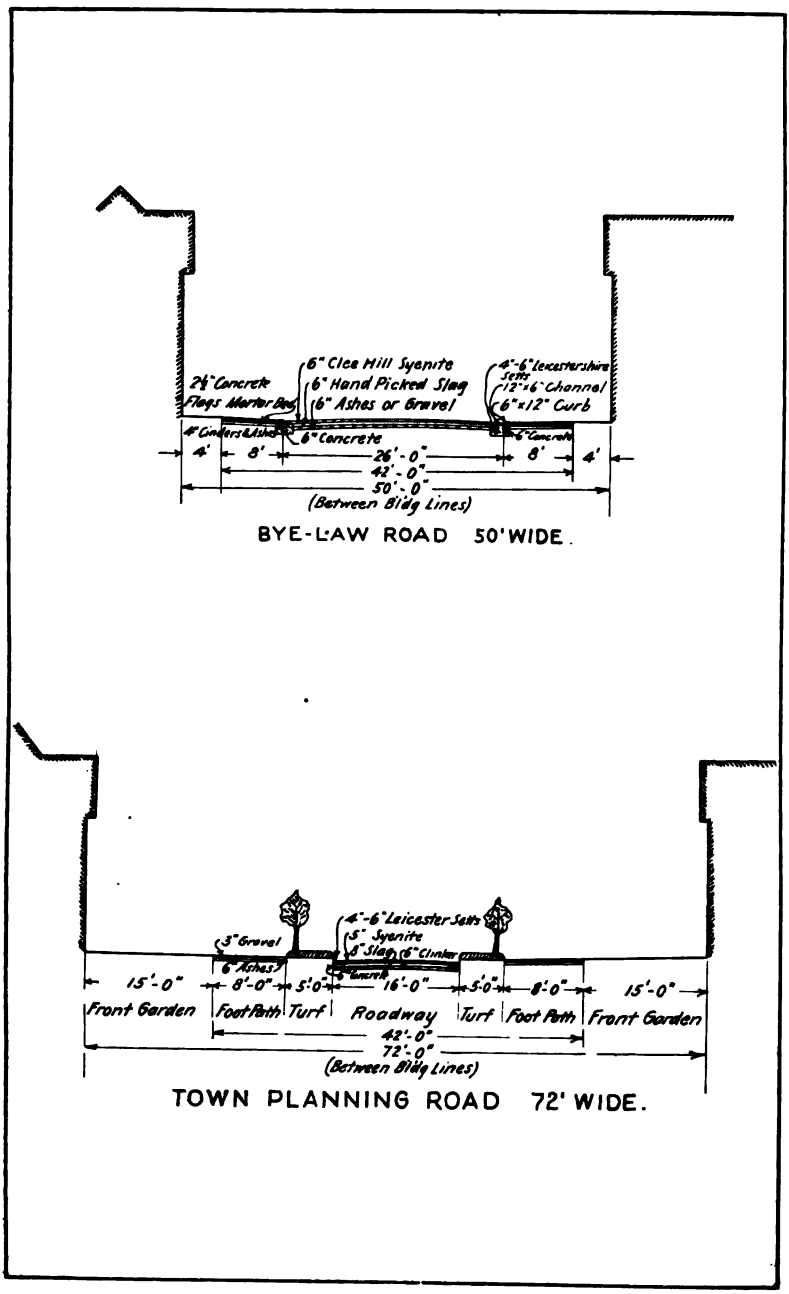
Fig. 2.) In the center of the island, eight, ten and even twelve story loft and factory buildings are common, and sixteen to twenty story loft buildings are springing up around the Union and Madison Square Districts, I presume to keep the Metropolitan Tower from getting lonely. "The long and short haul" has of course little to do with this subject. The essential point is that with factories away from lines of freight we go through four superfluous motions in getting goods from floats to lofts and back to floats. Contrast the development of the Brooklyn side of the river with the piers and harbor which Frankfort-on-the-Main is constructing, the docks of Havre, Liverpool and Hamburg, the scientifically planned factory districts of Vienna, Cologne and many other foreign cities, as well as the plans of Boston, Chicago, Los Angeles and San Francisco, and then ask why we haven't developed factory districts along the score of miles provided by Providence in The Bronx, Brooklyn, and Queens, for those who have eyes to see and courage to direct a city's growth along economic lines and in the interests of the cititzens who are not the owners of land in central Manhattan.

Deeply as we deplore "Death Avenue," it is partly due to the City's failure to provide or compel the railroads who enjoy sufficient franchises as a condition of those franchises to run their lines where they will be of practical service in developing natural factory sites, instead of reducing the City's congestion in an unnatural way, by the slaughter of innocent children and adults.

5th. The elimination of the cost of carfare as far as possible to the working population.

There seems to be a general idea that the workingman, whether his hours be from eight to five, or the more usual hours for the unskilled wage earner, from seven to six, is very anxious to spend an hour and a half six times a week, underground if possible, riding to and from his work. This involves of course in the latter case that his wife must have the comfort of getting up before five in the morning, and she can't get the house cleaned up till after eight at night when the wandering husband has had his evening meal. Subways under every avenue and in every direction is the great solution for unhappy housing conditions, we are told, and New York citizens aspire in the words of Browning, morning and evening, "to ride, ride together."

PLATE 38.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.



We need to get over the attack of "transititis" which is mostly largely induced by the germ, "land speculitis," of which New York is the paradise, and realize that the consumer of goods, who is to-day keenly aware of the increased cost of production, is paying the freight for these joyless rides, and that this cost benefits *no one* but the investor in transit lines, is not productive, but is a leakage in economical production. Even reduced fares will only reduce the leakage. We have nearly 700 000 workers in factories. A minimum of $30 a piece for carfare means $21 000 000 a year. The total wages paid in 1905 in all manufacturing concerns in the city was only $248 000 000, about eleven times what the ten cents a day carfare of the factory workers in the city to-day would cost. Moreover, the waste of time is a most important loss since city planning, if you will concede the correctness of my contention, promises the logical development of a city for the greatest good of the greatest number, because it robs the working population of that leisure and opportunity for becoming something besides an efficient producing machine, which is the inherent right of every man.

To construct fifteen or twenty story flat-level buildings for work in one borough, and five or six story flat-level tenements in the other three so as to give people the privilege of spending one-eighth of their working day in rushing from one to the other, is hardly an evidence of unbiased sanity. Clearly then, some future restriction is needed upon this massing of people in two separate parts of the city twice daily. People should live near their work, if possible within walking distance, especially those with over a seven-hour day. To ensure the possibility of good homes at reasonable rents for unskilled wage earners, within walking distance of their work, will unquestionably require new emphasis upon that part of the constitutional amendment which declares that no man can be deprived of life or liberty without due process of law. It will probably equally require an extension of the public powers of the state, both in respect to restrictions upon the use of land, and the exercise of the democratic art of taxation. To deny the possibility of such control over the American city's development, as has been successfully achieved in foreign cities under monarchical forms of government, is to acclaim the superiority of monarchical over our alleged democratic form of government.

6th. The decentralization of the City's business, pleasure and educational interests.

Only by decentralization of the office and factory districts as well as by the scattering and more reasonable location of theatres, music halls, lecture halls, etc., can the economy referred to in car-fare be effected. Coney Island, Gravesend and Flushing are a long distance from the Great White Way, and the reasonable and instructive features of drama, music and pleasure places must be located so that the enjoyment thereof will not involve for each time one-third to one-fifth of the price of admission. Munich has an interesting scheme, proposed by Henrici, for the creation of 18 civic centers. It was proposed at first to create each center as far as possible around some existing building and center of interest. As an economic factor, as well as in securing a better standard throughout the city, it is appropriate to call attention to the power in Germany of compulsory expropriation of land for purposes of Town Planning, nor must we permit ourselves for an instant to forget that in Germany many of the municipalities own from 10 to 50% of the land within their boundaries, while their systems of taxation are such as to give the benefit of improvements to those whose presence creates the demand for these improvements and virtually constitutes the effectiveness thereof.

7th. The provision of adequate parks, playgrounds and open spaces, with space for public buildings to furnish not merely sites but settings.

It is universally admitted that parks are the lungs of a city, and the emphasis upon the prevention of consumption which is so marked a feature of present day social effort, has emphasized not only the necessity for proper lungs, but for proper functioning of lungs. The city without adequate park area and playground area is like a human being with part of his lungs lost through the ravages of the tubercular bacillus.

The Playgrounds Association of this city have estimated that there should be at least an acre of park for every 250 citizens. We may, however, in the built-up sections of the city assume a more conservative condition for health, and yet the condition in New York City makes it clear that we are in a very unhealthy state. In 1909 Manhattan had a population per acre of park area of 1 589;

PLATE 39.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.

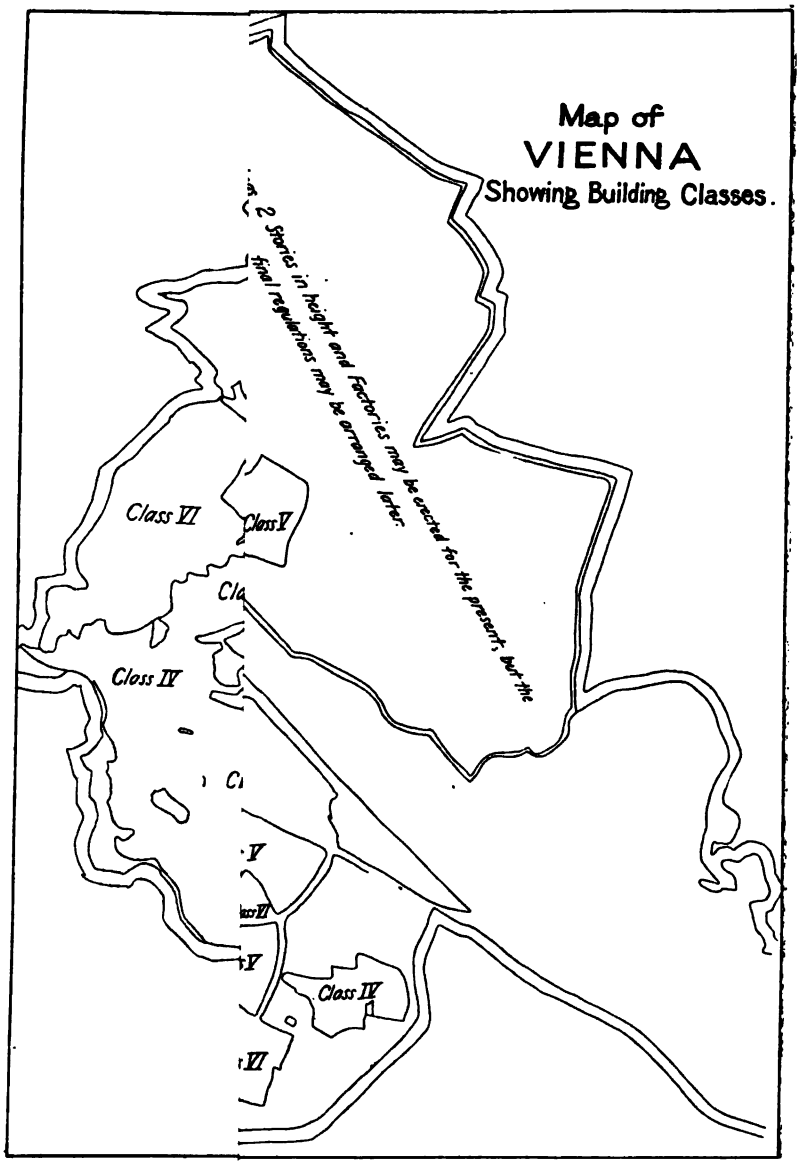
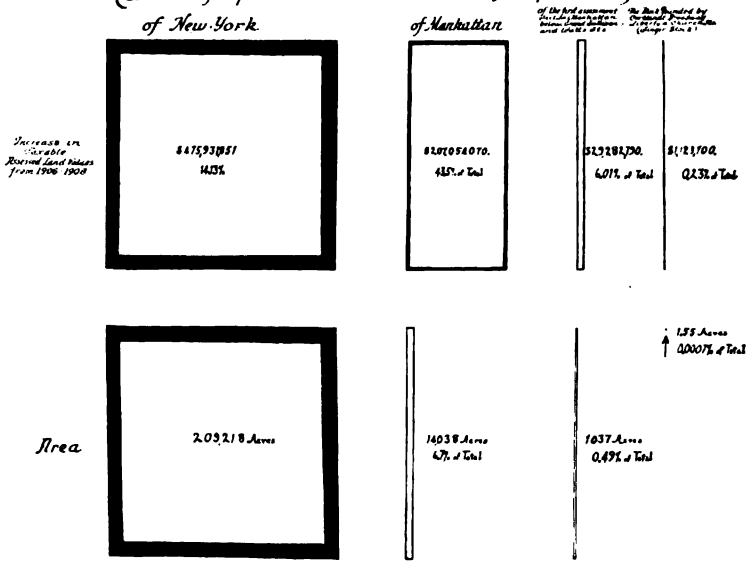

Map of
VIENNA
Showing Building Classes.
2 Stories in height and Factories may be erected for the present, but the final regulations may be arranged later.
Class VI
Class V
Class IV
Class IV
Class VI

PLATE 40.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.

Diagram ~

Showing the area and proportion of the total increase in Taxable Assessed Land Value from 1906 ~ 1908

(Exclusive of Special Franchises & Real Estate of Corporations)



To the Man who Can't afford to build a Sky-scraper!
One Result of intensive use of land is
Concentration of Land Values ~
Restrict this use and you distribute Land Values.

Brooklyn, 1 268; The Bronx, 83; Queens, 211; Richmond, 1 127. The total park area of Greater New York, mapped in 1909, was 7 221 acres. The normal park area, allowing one acre of park to every 250 people, would have been 15 944. *New York City, therefore, lacks to-day 8 723 acres of having a normal park area.* The reason for this shortage, as expressed by the City Planning Commission of 1807, is typical of the attitude of many cities on parks and playgrounds. *"When, therefore, from the same causes the prices of land are so uncommonly great, it seems proper to admit the principles of economy to greater influence than might, under circumstances of different kind, have consisted with the dictates of prudence."* We can, therefore, in planning a city make this provision before it is too late. New York City has paid as high as $5 000 000 per acre or $114.80 per sq. ft. for park land, while Diker Beach Park in Brooklyn cost but 3.6 cents per square foot and Silver Lake Park in Richmond but 4.6 cents per square foot. (See Plate 40.)

Whether a city should buy parks itself or the property benefited by parks should pay for them is practically another way of putting the question, Shall the city increase rents or not? Of course it is impossible in built-up sections of the city to furnish at reasonable expense a sufficient park area to supply the needs of the neighborhood, but such provision can be made in new sections of the city, and anyone who has seen the New Public Library to be, can appreciate the necessity of not merely having a building, but of having a setting for it. It is as true that a building fitly set is like apples of gold in a picture of silver, as that a word fitly spoken may be similarly characterized, and it is of supreme importance that we should not merely put up any public building where there is a breathing space, but that wherever this can be done without taking life blood and food out of the mouths of poor citizens, we should provide reasonable and effective spaces and æsthetic and harmonious surroundings. This can be better done where land is not worth three-quarters of a million dollars an acre, and the economic bearing of "City Planning" is seen, since a dollar in time often saves not nine, but nearly nine millions.

8th. Such control over the location and volume of buildings for manufacturing and office purposes as will enable the City authori-

ties to anticipate and provide adequate means of carrying passengers.

The office district below Chambers Street, in Manhattan, would accommodate in a recent year about 127 000 people, taking a reasonable factor of rentability and allowing 110 sq. ft. for each occupant. On the other hand, if we make this district exclusively an office section and permit all buildings to be a flat level of twenty-five stories, we should have over a million people accommodated in offices in the island's tip. With the number of people who daily visit these offices the total would probably be about a million and a half. (See Plate 41.)

We will all agree that no city has yet evidenced ability to create transit lines to handle such a problem as is created by our skyscrapers, and no city has the right to permit a citizen, acting from self-interest, to create conditions which could not reasonably be granted to every other citizen. We must recognize that a skyscraper is a quasi-monopoly, just as a street privilege is, and should be paid for as is any other franchise.

9th. The control of the development of new and unbuilt sections of a city, and the incorporation of adjacent areas so that their development may similarly be controlled.

This last point is one which has been especially well discussed by Mr. Nelson P. Lewis, in the City Planning conference at Rochester. We would also call attention to the fact that foreign cities have found it necessary to incorporate adjacent areas so that their development may similarly be controlled. (See Plate 42.)

The duplication of conditions in Manhattan, where we permit the poorer classes to be farmed out for exploitation by real estate speculators and tenement sweaters, must not be permitted in the other boroughs. That such conditions should be permitted in new sections of any city both Mr. Lewis and Commissioner Tomkins have vigorously denied, and it would seem logical to admit that because a city has permitted one wrong it is therefore not obliged to permit a continuance or duplication of that wrong. However, most cities now have at least the opportunity to enforce the better standard of housing for this working population, in the new sections of the city, and the City is unquestionably justified in refusing to sanction the duplication of unhealthy conditions merely because

PLATE 41.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
OF CITY PLANNING.

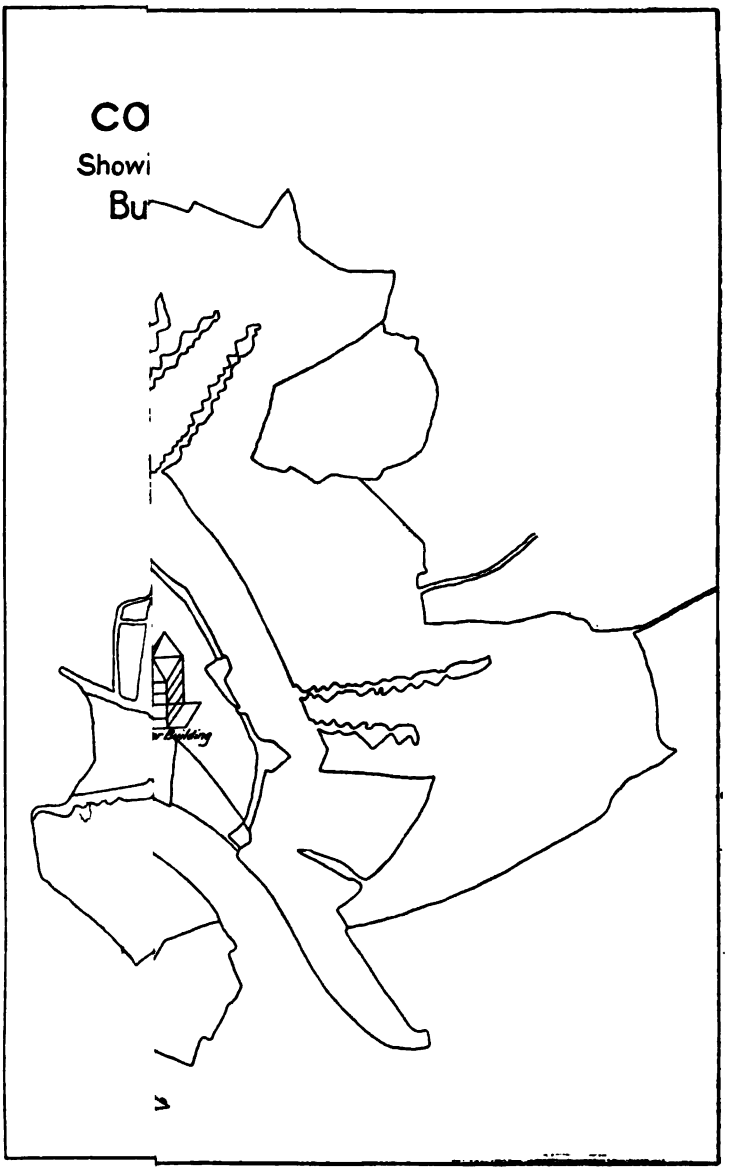


PLATE 42.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
MARSH ON ECONOMIC ASPECTS
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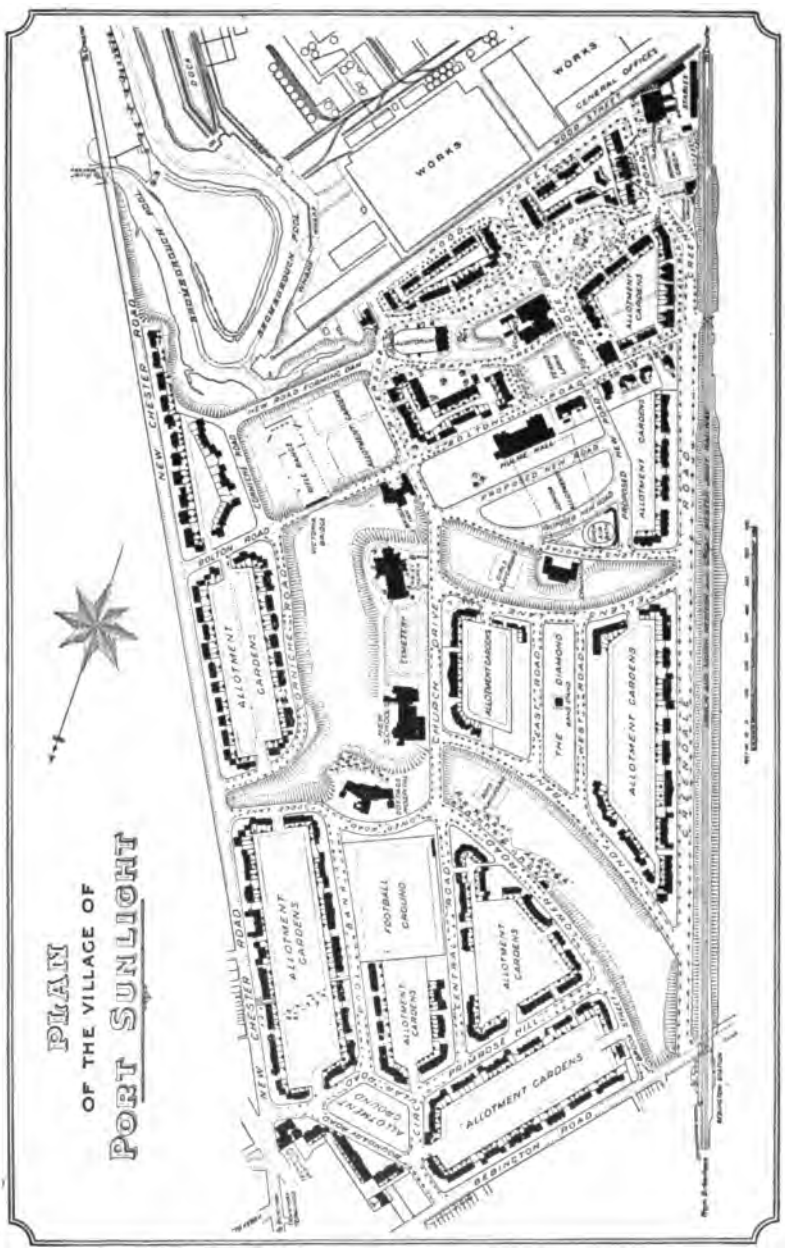

these conditions have grown and been condoned, if not sanctioned, by existing government in old sections of the city.

Berlin, Frankfort, Cologne, London, Paris, and Vienna, as well as many of our American cities, are showing the democratic tendency to preserve for the citizens normal conditions in their new districts. The laws of many foreign countries forbid any developer to lay streets unless in conformity with the plan already conceived by the government of the city. This means that the city is determined to plan its new districts, and that it refuses to abdicate its sovereign rights of government in favor of the real estate speculators or the jerry builder and tenement sweater. Although this survey of city planning is necessarily very brief, it may be stated again that it is a recognition of the fact that the city is for the citizens, and not for a privileged few. This recognition is essential to a proper consummation of city planning, and while we are free to admit that the details and the carrying out of the plans must principally devolve upon the engineers and architects, the formulation of the purpose of city planning is in the hands of those directly responsible for the conduct of the city. They must determine whether the plan is to be for the general good, or for the individual's gain; the engineer can practically carry out their decision.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—We are very glad to learn the views of Mr. Marsh concerning the important features of city planning, to which he has given much time and thought in connection with his work for the Congestion Committee and for the Congestion Commission which has recently been appointed by the Mayor.

Our American cities have invariably adopted a system of government based on leaving the individual as free in caring for his property as is consistent with what may be called the police powers, but the time seems to be at hand when it may be necessary to extend these functions if we are to provide for suitably housing the masses and for giving them surroundings that will permit of their proper development. Increased municipal activities in the line of improvements which must finance themselves or where the capital involved is too great to entrust to private enterprises is also another one of the future conditions which we are beginning to recognize as essential to proper city planning and growth in order to obtain or reproduce some of the admirable features of cities of the old world where other than a democratic form of government prevails.

We are glad to have our attention drawn to the lines which are certain to govern more or less largely in the future, and we can assure the author that he has given us much food for thought.

NELSON P. LEWIS, M. M. E. N. Y.—It is fortunate that The Municipal Engineers, who are likely to approach the subject of city planning from the purely engineering side, have had this subject presented from the viewpoint of one who might be called a social economist. The economic aspects of the problem which appeal most strongly to the engineer are likely to be those which relate to facility of movement along city streets, whether by ordinary vehicles or by transportation lines, and the cost of the street service, including maintenance and cleansing. The dignity and symmetry of the city plan is also beginning to appeal more and more strongly to the municipal engineer. If one were to judge by past performances in the City of New York, he might be justified in the conclusion that neither facility of movement, dignity nor sanitation had been given any consideration in the planning of the city, but that the sole aim of those responsible for our street system was to provide the maximum number of marketable lots and to interfere with existing conditions as little as possible. Some degree of symmetry there may be if an uniform, even though irrational, block dimension can be so dignified. The passion for this kind of symmetry has resulted in covering nearly the whole of Manhattan Island with a

gridiron of rectangular blocks, the result being that there is scarcely a site in the entire borough where a fine building can be seen to advantage, and it is impossible to go from one side of the lower part of the borough to the other side of the upper part without a series of right angle turns resulting in an increase of distance and a loss of time.

In Brooklyn, a number of towns were laid out, each with its own rectangular system prepared without regard to those adjacent to it, and while there are a few radial or diagonal streets, they appear to have been located without any particular reason, so that instead of the painful monotony of the Manhattan system, this borough has an unsymmetrical combination of symmetrical blocks which is sadly lacking in what are coming to be considered the essentials of a rational city plan.

In The Bronx, which was planned at a later date, the street system is much better. In that part of the borough west of the Bronx River the somewhat rugged topography compelled the laying out of a number of radial and diagonal thoroughfares, while in that part of the borough lying east of the Bronx River a number of such arteries have been secured by the simple and natural policy of giving the existing streets adequate width and making them the controlling feature of the plan.

The making of plans for the Boroughs of Queens and Richmond has not yet proceeded far enough to justify comment, but it is to be hoped that in view of the more intelligent appreciation of the essentials of a city plan, these boroughs will show a marked advance over anything which has yet been done in the city.

Mr. Marsh begins by defining city planning as "the orderly development of a city by which each section is arranged for the purpose for which it is best and most economically adapted, so that a harmonious entity is secured," and in order to secure this "harmonious entity" he believes that we must have a "wider extension and application of the police powers of the State." This is undoubtedly true, but in the writer's opinion the State will be very slow to extend and apply these police powers or to delegate them to the cities. We are not dealing with a made-to-order political capital like Washington or an industrial capital like Gary. We are immediately and vitally concerned with the great and rapidly growing City of New York, which had become great before we realized the importance of proper city planning, a city whose greatness is the result of the commerce and manufactures which developed along the lines of least resistance and where the founders of its commerce and manufactures thought it most advantageous and profitable to place them. Where they were established they are likely to remain, unless driven out by inability to expand, by excessive taxation, or

by hostile legislation, and if for these reasons they might find it necessary to move, they will be quite likely to go out of the city or out of the State, as a number of manufacturing plants have already done.

The policy which the author of the paper has in mind has been carried out with marked success by a number of German cities, a conspicuous instance being that of Frankfort-on-Main, where the city itself has purchased large areas of water-front property which it has improved by the erection of docks and the laying of railway tracks, so that this city is enabled to offer special inducements to manufacturers, and the sale of manufacturing sites will not only reimburse the city for its outlay, but will give it a substantial profit. In fact, the real estate policies of the German cities are attracting the attention of the entire world, the land which they have acquired both within and without the city limits amounting in some cases to a large percentage of the entire city area. The theory is that the cities themselves are entitled to a share in the increased values which result from their own growth and development, and the profit resulting from these increased values enables them to carry out large metropolitan enterprises which would otherwise be out of the question.

There would undoubtedly be much opposition to the adoption of such a policy by American cities. The reasons for this opposition are two-fold. First,—and this objection is one put forward in entire good faith,—it is generally believed that city officers are not to be trusted with the power to acquire property for what might be called speculative purposes for the municipality, for the reason that such a power would be corruptly used or grossly abused. Second, such a policy is vigorously opposed by those who are anxious to reap for themselves the benefit of any increase in realty values caused by the growth and development of the city itself. In other words, they appear to believe that the city's development should be exploited by those who are farsighted enough to anticipate it or who are fortunate enough to secure inside information, and that they should be enabled to reap the profit, while the theory that the city itself is entitled to share in the profit resulting from increased values brought about by its own growth appears to them preposterous. If, however, the great American cities do not adopt some such course, they will be unable to finance the big things which are essential to their future growth and development.

The consideration which is apparently uppermost in Mr. Marsh's mind is the decent and sanitary housing of the average wage-earner, and in order that this may be accomplished, he concludes that the land on which the homes of the wage-earners are built must not cost more than 40 cents a square foot ready for building, with roads,

sewers and sidewalks. This is equivalent to $800 for a city lot 20 by 100 ft. The lowest cost at which such a street could be improved with sewers, pavement and sidewalk, assuming a roadway width of 24 ft. and a very small amount of grading, would probably be $10 per front foot, or $200 a lot, with no allowance whatever for acquiring title to the street. This means that the land itself must not cost more than $600 a lot, while the owner will dedicate or cede the streets without expense. There are some such places in the city, but they have not the transit facilities the author regards as indispensable for his workingmen's homes. When such facilities come and when these homes have been built, it is very doubtful if the assessors will be satisfied with this land value of $800 a lot. When the taxes go up the rents will not lag behind, and our workingmen will be obliged to move further out, with a longer journey to their work and perhaps without facilities for riding.

The keen interest lately manifested in the subject of city planning promises well for the future, if it can be directed along practicable lines. Less than a year ago the British Parliament passed a Town Planning Act which was designed to furnish, through the Local Government Board, a medium by which every small town as well as every large city can make intelligent and farsighted plans for future development. While the local authorities are supposed to take the initiative, the Act provides that in case of their failure to do so, the Local Government Board may step in and do it for them. This movement in England appears to have been due primarily to a desire to improve housing conditions, but as recently developed it goes much further and extends to the dignity and symmetry of the street system, as well as its adaptation to present and future traffic requirements.

We have heard much in recent years of those overworked words "the city beautiful" and "civic centers," but the time has come when the municipal engineer must give his earnest attention and his best talents to the planning of our cities along more intelligent lines than those which have heretofore been followed.

Mr. Marsh has done well to bring this subject to our attention.

CALVIN TOMKINS.*—I have listened to Mr. Marsh's paper with a great deal of interest and fully appreciate the good work which he is doing, although my opinion is slightly different from his in regard to some of the conclusions which he reaches. I first had to deal with this question in the Municipal Art Society, of which I was president, six or seven years ago. This kind of discussion was then a novelty, although some cities, notably Washington and Cleveland, had made progress in planning improvements ahead, but little had been done up to that time in the United States as compared to

* Commissioner, Department of Docks and Ferries, New York City.

what had long been the policy of the German cities. Since then, however, this movement has acquired great momentum through force of circumstances, and American cities are now generally appreciating the necessity of planning their development in advance.

The great difficulty we have to contend with in the United States, as Mr. Marsh has pointed out, is that we do not yet understand the necessity for or the beneficial results of such pre-vision. In addition, European cities usually are governed by experts, who, after acquiring experience in small cities, are promoted to responsible positions in the larger cities. Here the political government of our cities on party lines has produced most unsatisfactory results. For many years to come we cannot expect to rely upon technical, expert control, such as exists in Europe, and instead we must depend upon an intelligent body of public opinion created through discussion and largely the result of disinterested activities of private citizens. Such an understanding of public affairs is gradually developing and is having a most salutary effect upon controlling the vagaries of shifting administrations. Continuity of purpose is becoming much more evident than it was a few years ago. Technical bodies, such as the Municipal Engineers, constitute one of the most important factors working for this change.

Mr. Marsh has particularly called attention to the necessity of not permitting the incorporation of small outlying sections into the central district until an improvement plan has been imposed upon them. I anticipate that such a thorough-going method of procedure will not be available in the United States for many years to come, at least to the same extent as it is now being availed of in Germany, but much can be done by the municipality to force a suitable system of streets, parks and public improvements generally upon these outlying districts. A cheaper and more expeditious procedure for condemnation of lands, beneficial assessments on private property affected by public improvements, and the procedure known as "excess condemnation" which actually provides for public acquisition of lands in advance of improvements and then permits the sale or leasing of such lands at their higher valuation after the improvements have been made, all these methods facilitate the planning of new areas and the reorganization of the older and more congested parts of the city. We can still do as we like with the greater part of Queens, Staten Island and the Jamaica district in Brooklyn, but the problem is a much more difficult one in the rest of the City. Improvements must be made to pay for themselves out of increased land values if we are to obtain them promptly. The proposed extension of Sixth and Seventh Avenues south is an instance in point. It is possible to extend both of these avenues under a policy, such as is above outlined, without serious expense

to the City itself. The lands in this vicinity are at the present time of comparatively small value and this value will be greatly increased by the improvement. If, coincidentally with the extension of these streets, provision should be made for west side subways through them, a resort to excess condemnation would doubtless make the improvement a very profitable enterprise for the City on account of the still greater value which would be given to the lands affected. It is also possible under this procedure to control the character of the buildings which will be erected along the new streets, and this is a subject of vast importance to all municipalities. Under existing conditions, when a broad avenue is laid out it is too frequently promptly vulgarized by a character of building construction which should not be permitted and which has the effect of minimizing the value of all surrounding properties. The Manhattan approach to the Blackwell's Island Bridge, which will soon become necessary, is another case in point, and this difficult and expensive problem can probably only be solved in an adequate way by a resort to excess condemnation. I do not see how the more congested and backward parts of lower Manhattan and some districts in Brooklyn can be reorganized in such a manner as to be suitable for modern requirements except by making the improvements pay for themselves.

Congestion of any sort is undesirable, but this is a very different thing from the intensive use of land by tall buildings. If proper air and light shall be provided in the streets and in these buildings, such intensive use is not undesirable and I believe is inevitable at the center of this great city. Nothing can prevent the continued construction of tall buildings in lower New York, the purpose of which is to bring people closer together and thus provide facilities for handling business quickly and conveniently, but it is important that the structures should not interfere with each other or with the street lights. If the City shall insist upon maintaining the street lights by providing for an angle of light in the streets, I think that self-interest will generally stimulate private owners to prevent the crowding of buildings against each other on the side lines in such a way as to interfere with the side lights. The tendency will also be to promote the block as the unit for large building construction instead of the single lot. An entire block with the street lights properly guarded on the outside by a V-shaped angle of light and similarly guarded as regards the interior court lights is the most suitable kind of a structure to place upon valuable land, and I see no reason for limiting height otherwise than by insisting upon a suitable angle of light in the public streets. It may also be possible to so change the law as to compel adjacent private owners not to interfere with each other's lights. The doctrine of "Ancient Lights" in the English law has been generally nullified in the

United States, but I am informed on good legal authority that it is possible to again make it effective.

KENNETH ALLEN, M. M. E. N. Y.—The problem of congestion in Manhattan differs from that elsewhere, partly on account of its magnitude and partly on account of the peculiar topographical conditions, by which growth is limited to one direction only. With the continual influx of foreigners, many of whom remain on the Island of Manhattan in spite of high rents, and with the tendency to concentrate important financial and mercantile interests in its southern end, it is no wonder that questions pertaining to the relief of congestion crowd to the front with increasing emphasis.

Foremost among these are questions relating to rapid transit, and in considering these it should be clearly borne in mind that while the extension of subways facilitates the use of suburban areas for homes it also serves to increase the congestion of business centers by enabling greater numbers of people to concentrate in them.

Tenement-house conditions in lower Manhattan call for betterment in the way of housing, playgrounds, etc., and the urgency for this will doubtless continue for many years, especially in that large area lying to the east of the Bowery. From such casual observations as the writer has been able to make, it is his belief that west of this thoroughfare the land should and will eventually be devoted exclusively to business purposes. For dwelling purposes it is already entirely unsuitable. Shipping interests will naturally occupy the water-front and the development of the district given up to high office buildings will probably continue. But if this development is as unrestricted as in the past the writer believes that it will be detrimental, resulting in overcrowding of streets and car lines in spite of all efforts to the contrary. It is true that the resulting inconvenience to travel and lack of sunlight on the lower levels will automatically tend to restrict development in this direction, but such restrictive tendencies invariably lag behind their need and are difficult or impossible to remedy. For these reasons the writer believes it important to limit the height of buildings here by law.

The suggestion made by the author, that factories and other industries requiring the service of large numbers of workingmen have no place in lower Manhattan and that they should be encouraged to utilize the cheaper sites already available in the suburbs, is sound and deserves support.

In the matter of developing outlying centers of population such as are found in parts of all the other four boroughs of New York, the main features should undoubtedly be under the control of some central authority having, in addition to advisory and veto powers, the authority to lay down such general lines of improvement as will ensure the harmonious development of the City as a whole.

GILBERT ELLIOTT.*—Every engineer present will, I am sure, agree with me that we ought to build a more convenient and a much more magnificent City than we are now planning for. That we should have more diagonal highways, more wide thoroughfares, more parks, playgrounds, more parkways and boulevards, and civic centers for our public buildings, but these things cost money, and the question is where to find it, and it apparently is not being found at present. The fault is perhaps in our present system of assessing for benefit, and of home rule through the Local Boards. The burden of deciding in favor of an improvement of the character mentioned, is usually thrown upon the local aldermen, who must bear the brunt of the objections of those who do not wish to pay the expense. This is, I think, a hardship which the aldermen ought not to be called upon to face. They should be relieved, and one way to do this would be to have the Board of Estimate take the responsibility of making and changing the City plan as was apparently intended by the Charter, and for the borough presidents not to throw the burden upon the aldermen of bearing the local objections. For the local man in a new and sparsely settled section naturally objects to assessments. Narrow streets for the time being, are as valuable to him as wide ones, in fact the cost of making and paving is less, but it is afterwards when the congestion begins that the advantage of the wide thoroughfares, parks and boulevards is perceived. Then, however, it is usually too late to lay them out, because of the high cost entailed by the necessary destruction of buildings, so that if these improvements are to be obtained on a scale worthy of the future city, the expense should be at least shared by the later portions or else it must be done by some authority further removed from the local interest than is the alderman.

Much interest has lately been taken in the plan to have each borough pay part or all of the cost of such improvement within the borough, and considering the City's financial plight, it is perhaps the most available method. That we should continue to sit still and see the City developing without these necessary facilities is hardly to be thought of. Nothing pays the City better than such improvements which attract and hold visitors of wealth, able to locate where they please.

Money spent in New York by the stranger is not less than a thousand millions per annum, probably twice that great sum. It is in cash, and the profits on it are huge. Paris realizes the gain from this business, and is spending large sums to still further beautify the city. Other American cities are striving for a share of this rich prize. New York ought not to lag behind.

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*Counsellor-at-law, 44 Court Street, Brooklyn.

ROBERT R. CROWELL, M. M. E. N. Y.—Mr. President, in the Borough of Queens, we have very cheap rent and very cheap houses, and all we need now is the occupants. I think the engineers of this Society might very well afford to live over there, but not at the rate which the author recites. In fact, there is not any property in the Borough of Queens to-day, except on the meadows, which can be bought except at $5 000 an acre, and you cannot put up any house in the Borough of Queens to-day, either detached or two together, that can be rented for $12 or $14 a month.

The matter of planning a part of this City is quite ripe in Queens Borough. In the case of Myrtle Avenue, the present street is 70 ft. wide, runing from Richmond Hill to the Brooklyn City line. The first street on the south of it is about one mile distant, and the first street on the north of it is over one mile; the intervening land is made up of cemeteries and parks. It will be absolutely impossible to get another street between the northerly and the southerly streets, consequently, that 70-ft. street, Myrtle Avenue, must of necessity in the very near future take care of all the east and west traffic from about thirty square miles in the Borough of Queens. This matter was taken up and four or five maps were adopted which showed the street as laid out 100 ft. in width. There is one small section which has not been widened and this map, which was about to go before the Board of Estimate and Apportionment was the matter under consideration. The President of the borough gave the abutting property-owners a hearing. There were about forty who came to object to the proposed widening. There was not a man there to speak for the approval of the map.

About two years ago, however, we had quite a number of civic societies which were advocating 100, 150, and 200 ft. roads, parks, boulevards, etc., but they have all disappeared for one reason or another. The property since that time has not deteriorated although they want to get rid of it; I do not know why, but I know there is nobody left who wants wide streets.

I will give you a sample of the arguments made by one of the gentlemen: "Mr. President, the public do not want these improvements, and they should be listened to. Ninety-nine per cent. of the entire property-owners affected by the proposed opening of this street will propose to leave the street as it is to-day. There is absolutely no necessity for the widening of the street. The engineers are to blame. Listen to the wishes of the public in this matter. We petition you to change these maps as we want them. It is time that the public were listened to; let the public have their say; the engineers are not the public."

That is the kind of an argument that was made before the Borough President. They tell us to-day that they have sufficient room, but

if the City should feel that conditions necessitate the widening of the street, the City should pay the bill and not the people deemed to be benefited by the widening.

Now, these are the conditions that we have to look after. Mr. Tomkins has spoken about the extension of Seventh Avenue, suggested putting an assessment on the abutting property-owners and to take sufficient lands so that it would be possible to sell it over again and probably pay what it cost the City to make the improvement, but who is going to supply the money in the first instance? If that is going to be a benefit to the property-owners, then it is proper to assess the property-owners, but suppose you take more land than you really need for the improvement, would you charge this against the abutting property-owners? This might confiscate their property and the City would hold this excess property indefinitely or it might sell the excesses at once, but the money would go into the Sinking Fund. The people who had paid the original amount of money as an assessment would not get any part of it, so that they would be assessed for something that the City would be benefited by, not only increased taxation but also a profit which would be derived from the sale of the excess property.

City planning in Manhattan is one thing, but planning in the Borough of Queens, having it approved by the proper authorities and having the people approve of what has been done is quite a different matter.

I would like to call attention to another thing that Mr. Marsh referred to, and that is the matter of gardens in the German settlements in Europe. Nearly every house in the Borough of Brooklyn has a small yard in the rear from 40 to 50 ft. in length and from 18 to 25 ft. wide which could be used for gardens. I think if you will go into the back part of the houses and look out into the yards, you will not find over one garden in any one block in the City of Brooklyn. The people of this borough, or any of the rest of the boroughs, do not take much interest in gardens. In Germany, the women generally take care of the gardens, not the men. I do not think the matter of gardens gets much attention in the Borough of Queens or by the general public in the Greater City.

BENJAMIN C. MARSH.—Mr. Nelson P. Lewis has emphasized in his discussion the fundamental difference between the government of American cities and the government of foreign cities and uniquely the German cities. American cities distrust their elected officials and put every conceivable difficulty in the way of their free and needed activities, not chiefly, I believe, as Mr. Lewis suggests, that the citizens feel that such power would be wrongfully used and grossly abused, but for the more fundamental reason, to which he later refers, of the opposition to the adoption of a policy of real

government of American cities by their elected officials. This objection to the adoption of a policy of elected official rule in American cities is that the great interests of the city, real estate, manufacturing and transit, demand for themselves the right to oppress the people and make them work for them with no regard for their health or their rights, and the real estate interests uniquely insist that they have a right to farm out the entire city's population and reap for themselves the benefits of any increase in realty values caused by the growth or the development of the city itself.

Mr. Lewis has done a great public service in calling attention to this fact in unequivocal and unmistaken terms. His reference to my suggestion that the land on which the homes for wage-earners are to be built should cost not more than 40 cents per sq. ft., ready for building, with roads, sewers, sidewalks, etc., calls attention to the fact that the essential for such normal housing of our wage-earning population is cheap land. There are vast tracts in New York City, including the Boroughs of Richmond and Queens, where lots to-day do not cost over $200 to $300, and this can be made ready for occupancy at a very small expense, as Mr. Lewis states, not over $200 per lot, with allowance to acquire title to the street.

It will be only when the community is just to the wage-earners and creators of land values that we shall have in New York City such housing conditions as our wage-earners are entitled to. The distribution of factories of course, as noted in this paper, will enable the workingman to pay higher rents, since he can economize on the cost of transit a sum of at least $30 per year.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 58.
PRESENTED SEPTEMBER 28TH, 1910.

STUDIES AND EXPLORATIONS FOR THE HUDSON RIVER CROSSING OF THE CATSKILL AQUEDUCT.

BY SAMUEL D. DODGE* AND WILLIAM B. HOKE.*

WITH DISCUSSION BY
ARTHUR S. TUTTLE, ROBERT RIDGWAY, CHARLES P. BERKEY,
WILLIAM F. JOHNES, GEORGE A. TABER, ERIC T. KING,
WILLIAM B. HOKE AND SAMUEL D. DODGE.

In a paper delivered before this Society, on March 25th, 1908, Mr. Ridgway has shown why the various other proposed locations for the aqueduct across the Hudson River were abandoned in favor of the one at Storm King, and why the projects for a bridge, for a steel-lined tunnel driven with compressed air through the earth of the river bottom, and for steel pipe laid in trenches in the river bed were eliminated, bringing our studies to the proposition of a deep tunnel in the solid rock. The problem was then to prove the feasibility of a deep tunnel and determine the depth at which to drive it.

The hydraulic gradient of the aqueduct at this point is about four hundred feet above the surface of the Hudson River, so that the internal pressure when this tunnel is in operation, will be correspondingly great. During construction, on the other hand, the waters of the Hudson, many hundred feet above, will exert a material external pressure; consequently, a very substantial thickness of sound bed rock must be left above the tunnel at all points. The minimum thickness permissible has been considered to be 150 ft.

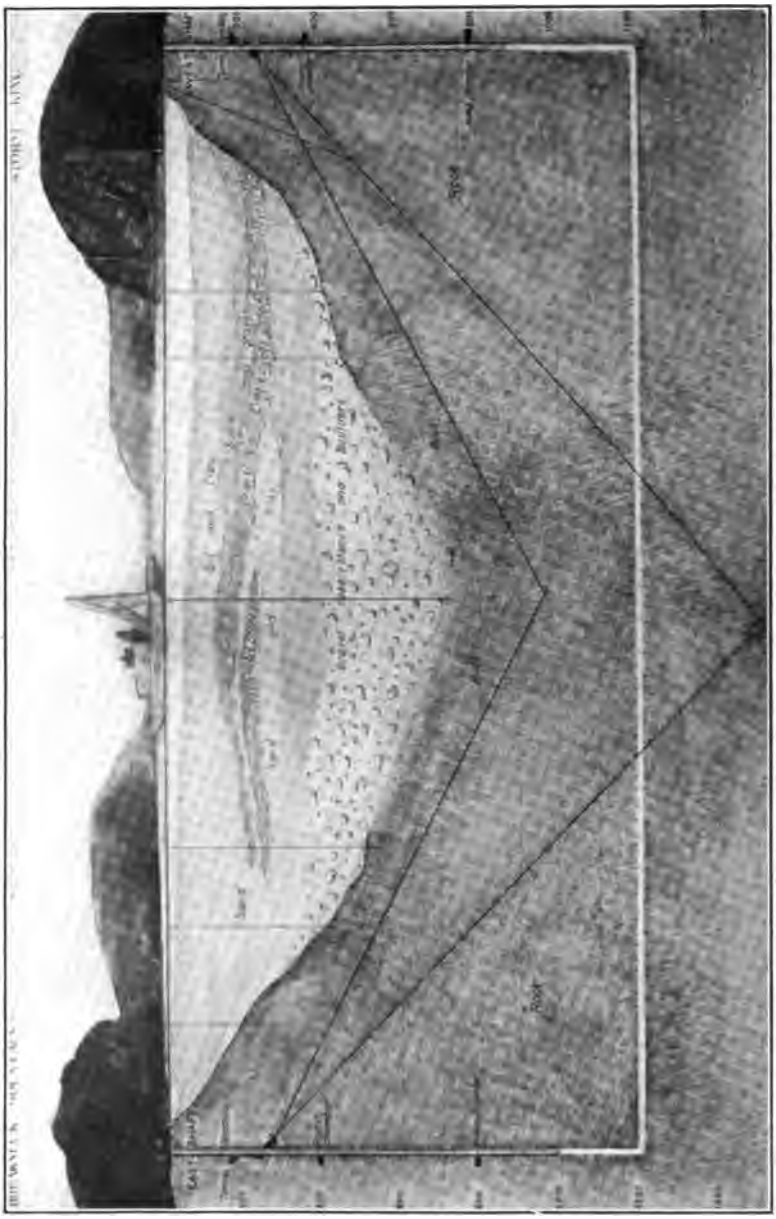
* Assistant Engineer, Board of Water Supply.

With that question settled, it can be seen that a profile of the rock surface was highly desirable and would make the fixing of the elevation of the tunnel very easy. (See Plate 43.) A determined effort was at first made to locate this profile by borings through the river bottom, but experience with the first borings, of the expense and time required to get down to bed rock, soon showed that it was out of the question to locate enough points on this profile in this way to establish it with certainty. Moreover, from the first, it was realized that the possibility of crevices or seams existing undiscovered between vertical borings, however near together they were placed, would require that the evidence afforded by them be supplemented by other information of a more certain character. While the effort has been continued to get information this way, other means have been sought for conclusive results.

Vertical shafts had been started near the river's edge on both sides to explore the rock and with the idea that, if investigations turned out favorably to this crossing, they could be made a part of the waterway. It was next proposed that inclined drifts be started from the bottoms of these shafts, which were then about 250 ft. deep, driven downward and under the river, while the rock ahead of and above them was explored by horizontal and upward inclined diamond-drill holes which would go to the surface of bed rock, thus determining the profile from beneath instead of above. (See Plate 44.) A number of well-grounded objections led to the dropping of this scheme in favor of the one finally adopted and described below.

If, as it seemed, the profile of the rock surface could not be determined, it was still possible to find a safe location for the tunnel by the use of inclined diamond-drill borings from the bottom of the shafts, prolonged to a meeting near the middle. (See Plate 43.) These would prove the existence of continuous sound rock on the line followed by them and the tunnel could be located 150 ft. or more deeper. They would give negative information and might fix the tunnel at a greater depth than necessary, but the importance of early completion of the aqueduct made the time element outweigh the possible additional cost of the unnecessary depth, which could be avoided only by a long-drawn-out system of exploration. This method was adopted and has been carried to a most successful conclusion.

PLATE 43.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.



VIEW AND CROSS SECTION LOOKING SOUTH ON LINE OF AQUEDUCT CROSSING OF HUDSON RIVER.

On August 23d, of this year, a pair of these inclined borings from opposite sides of the river, driven through bed rock for their whole length, crossed near the middle of the river at a depth of 955 ft., proving at least, that the gorge is no deeper than that. We had hoped to give in this paper positive information of the depth to bed rock at Hole No. 24, which is being put down vertically through the river bed almost exactly over the point of crossing of the inclined borings; on September 1st, Hole No. 24 was bottomed on granite which was thought very likely to be bed rock, but the diamond drill passed through it, proving it a boulder like several others that have been encountered above it, so we can say only that bed rock is deeper than 749 ft.

All elevations and depths in this paper are referred to Board of Water Supply datum, also that of the United States Coast and Geodetic Survey, which is mean tide at Sandy Hook.

The whole problem has thus been attacked in the following ways:

1. Study of the geology.
2. Vertical borings from the river to give the profile.
3. Test shafts at the sides of river to show the quality of the rock, to give starting points for the inclined borings and to have the waterway in progress during the time occupied by explorations. With these should be included four diamond-drill borings made from the shore to try the quality of the rock.
4. Inclined borings started from deep down in the shafts, to prove the existence of continuous sound rock on their line.

Study of the Geology.

The geology of the Hudson Gorge has received a great deal of attention, in which the services of several experts have been enlisted.

The two principal questions to be answered were: What is the depth of the gorge, and what is the quality of the rock through which the tunnel will be driven?

Concerning the depth of the gorge, the data at hand when studies were begun, were the physiography of the neighborhood, known depths to bed rock in the river at Pegg's Point, 13 miles

upstream, where the Board of Water Supply had put down three core borings (see Plate 53), some evidences of the ancient gorge in the ocean floor off New York Harbor, and a general knowledge of the geologic history of the region.

It was at first thought that the gorge is probably not more than 400 ft. deep and that, as the last of the erosion was done by the glacier, it is of a U-shape with a wide level bottom. When boring No. 10 went down 608 ft. before reaching bed rock, it indicated a probability that the Pegg's Point borings had not found the lowest part of the gorge at that place and consequently that they could not be used with any confidence in making deductions. The depth must be determined from a transverse profile constructed with evidence in and near its own plane. As the bottom was now proved to be far below the gorges of tributary streams in the vicinity, one eminent authority adopted the theory that there had been a period of active erosion by water in the Hudson Gorge after the ice sheet had covered the rest of the surface and put an end to fluvial erosion in the tributaries, and that the profile of the gorge had not been greatly changed by the glacier afterwards. He accordingly assumed the cross section characteristic of *a stream,* namely, a wide flaring V with sides that grow steeper as they go down. The slopes of the mountain sides above the river being used in conjecturing the shape and depth of the gorge below (see Plate 45, Fig. 1), it can be seen that it makes a good deal of difference whether the V, or the wide bottomed U is assumed.

The evidence of the later borings enabled the geologists to make, more confidently, definite estimates of the depth. Professor James F. Kemp and Dr. Charles P. Berkey, both of Columbia University, in their latest report, place the probable depth at between 800 and 900 ft. below sea level, but disclaim any certainty in the matter; they adhere to their belief that the present gorge is largely the result of ice erosion and that it is U-shaped. Professor William O. Crosby, of the Massachusetts Institute of Technology, who advanced the V-shaped gorge theory, said that the depth on the aqueduct line "is certainly not less than 800 ft. and that 1 000 ft. is not highly improbable"; he holds further that bed rock is considerably higher on this line than it is further south, believing that there is an escarpment in the bottom of the gorge approximately in line with

PLATE 44.
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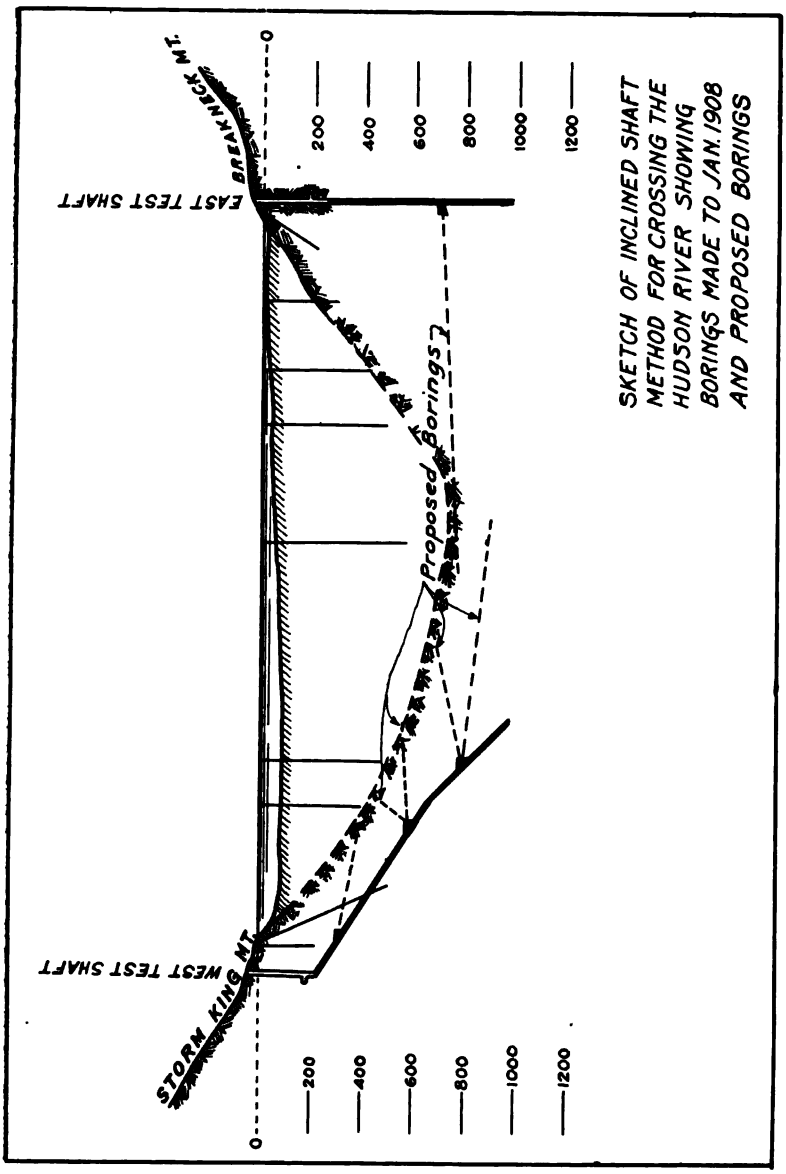
OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.



PROJECT FOR EXPLORATION BY INCLINED DRIFT AND BORINGS.

the bold southern faces of Storm King and Breakneck Mountains (see Plate 45, Fig. 2, and Plate 46, Fig. 1), which formed a cataract in the time when the river flowed in direct contact with its bed rock. Both of these estimates were made without the information that we now possess from the inclined borings, that the gorge is less than 955 ft. deep and from vertical boring No. 24 that it is more than 749 ft. deep.

Concerning the quality of rock to be tunnelled, all authorities are in virtual agreement. The large exposures in the faces of Storm King and Breakneck (see Plate 45, Fig. 2, and Plate 46, Fig. 1) give excellent opportunity to examine the hardness of the rock and the larger features of its structure, while the shafts and borings have proved that it has the same character under the river. To quote freely and by selection from Professor Crosby's various reports:

"Storm King and Breakneck Mountains are, except for a few dykes, wholly composed of granitic rock and it is just here at the northern edge of the Highlands that the granitic and gneissic rocks of the entire Highland district have their most uniform and massive development. All available evidence indicates the perfect continuity of this granite beneath the river. Disregarding the difficulty of excavation and the merits of formation as to stability and efficiency of the tunnel, the granite and gneiss are the strongest and most stable and durable rock of the region. On account of high rigidity, they are capable of maintaining open cracks or fissures (see Plate 46, Fig. 2), but these are not as in limestone, subject to widening by solution, and we may confidently expect that, unless due to geologically recent movement, they will be found cemented and sealed by secondary minerals. Of any recent faulting, the indications are that it is slight and superficial. It is not improbable that before the excavation of the deep gorge by water and ice, this central part of valley was marked by deep zones of decay, but such zones are a product of surface agencies and in view of great depth of Hudson Gorge, it is practically certain that erosion has cut far below the bottoms of any such zones of decay. Since the glacial period, the bed-rock floor has been deeply buried with glacial drift and constantly below level of ground water and so chemical deterioration of bed rock is hardly possible."

Vertical Borings from the River.

Wash Borings.—The earliest attempts to get down to rock were made by wash borings, pure and simple, under Agreement No. 15

with F. W. Miller. This is a cheap and rapid method of exploring and was used on a number of different lines, only for preliminary information to assist in deciding on the best route for the aqueduct. When more positive information was required the contracts and agreements for borings required that, when rock was reached, core borings should be made into it for a sufficient distance to at least prove that it was bed rock.

The wash boring method consists in sinking a line of iron pipe about one inch in diameter by means of a water jet forced through it to loosen the material below, by working and twisting with a grip and handles for two men, and by pounding with a maul. A larger pipe is put outside the jet pipe and carried down far enough to act as a casing through the soft mud of the river bottom, to keep the hole open and allow the collecting of samples of material at the bottom of the jet rod, brought up by the wash water. A small scow with a derrick and hand winch and a hand pump are the necessary equipment.

The small cost of the plant makes it an inexpensive method of boring, but it is of course not suited to great depths nor to a material containing boulders, for when something is encountered which will not wash away the boring stops and it can only be assumed that bed rock has been reached. A set of these borings were put down across the river near our present line; they gave surprisingly consistent results indicating bed rock with an almost level profile at a depth of about 160 ft., which is in fact the top of the layer of gravel developed by our later and more thorough investigations (see Plate 43), thus showing how unreliable wash borings are for bed rock investigation in this kind of ground.

The force consists of a captain or foreman, about four deck hands and three men in the boring work.

Number of these borings put down at Storm King line was	18
Aggregate length in water	905 ft.
" " " earth	1 746 ft.
Average progress per day in earth	175 ft.
" " " " " " and water.	265 ft.
Contract price for water and earth, per foot	$0.90

PLATE 45.
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DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.

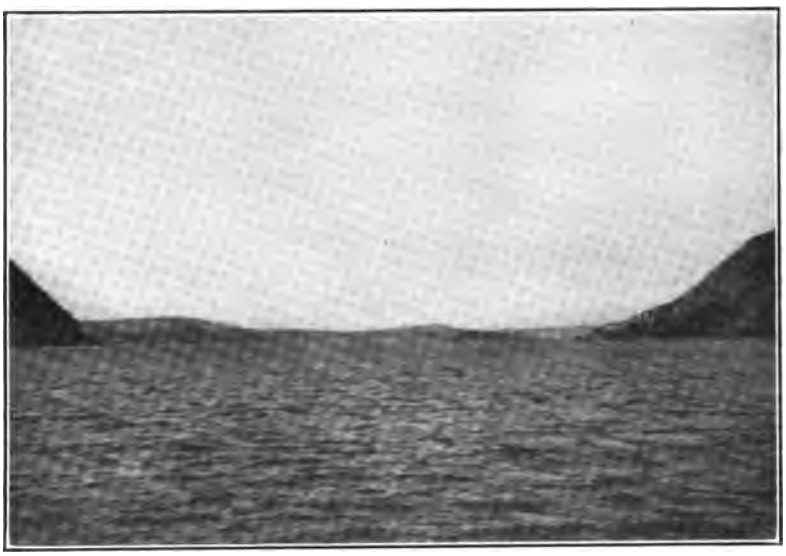

FIG. 1.—HUDSON RIVER AT AQUEDUCT CROSSING, LOOKING NORTH.

FIG. 2.—SCOW MAKING BORING IN HUDSON RIVER, STORM KING MOUNTAIN IN THE BACKGROUND.

Core Borings.—Core borings are so called here because the contract requires that samples of the rock, when it is reached, shall be taken in the form of cores cut by a diamond drill or other rotary cutting device, although the drilling which produces this core is a very small part and the easiest part of the work upon such a boring. The task of getting through the earth overlying the bed rock is one of very great difficulty. The necessity of working from the surface of the water with strong currents in alternate directions, exposure to rough water in times of storm and danger of collision from passing vessels, together with the difficult nature and great depth of the material, make it an unparalleled problem in underground exploration.

All of the core-boring work on the river at the Storm King line has been under Contract No. 1 with The American Diamond Rock Drill Company, but has been done by their assignees, The Phœnix Construction Company.

The equipment which experience has shown to be best and which is now in use, is a pile-driving scow 35 ft. by 100 ft. with ways 60 ft. high (see Plate 45, Fig. 2), a hoisting engine of 40 h.p., with two 7 in. by 10 in. cylinders and two 12-in. drums, two 12 in. by 7 in. by 12 in. pumps with capacity for 100 gal. per minute each at 120 lb. pressure and a 60-h.p. boiler, casing and wash pipe of 18-in. and 14-in. steel-welded pipe and 10-in., 8-in., 6-in., 4-in., 2½-in., and 2-in. extra heavy wrought-iron drive pipe with screw joints and extra long sleeve couplings, a drilling machine, 1¼-in. rods and enough diamonds for two bits. When the casing is surely seated in ledge and drilling under way the large scow and other equipment for wash boring can be dispensed with, the drilling machine being carried on a platform clamped to the casing, and pump and boiler kept on a scow about 20 ft. by 30 ft.

The scow is kept in position by at least six anchors at bow, stern and four corners; these must be from two to three tons each and have leads of 400 to 500 ft. of ⅞-in. wire cable. The severe gales and rough water encountered at times make it hard to keep the scow exactly in position, while any movement, if it is toward the hole, is likely to bend the standing casing and destroy the boring.

The general method of boring is to sink first a line of large casing as far as possible without too severe driving, then to put

down the next smaller size inside of it, "telescoping" as it is called, and continue downward again, the telescoping of casing being repeated when necessary, until bed rock is reached. A line of casing, of course, encounters skin friction against the drift material only below the bottom of the next larger casing, and in general an advance of 100 ft. or more should be made with each size though the first two sizes should make considerably more than that in the fine material which lies on top. The importance of not having too much frictional resistance on a line of casing comes from the necessity not only of moving the line down but of being able to draw it back, so that its end will be out of harm's way when blasting is done, hence care is taken against forcing when much resistance is felt. In the early work before the great depth of the gorge was known, and when the contractor knew less of how to do this kind of boring, the mistake was made of starting with too small casing and so coming down to the smallest size practicable while still a long way from rock; this made the last of the work on these holes excessively difficult and one of them had to be abandoned in an unfinished condition for this reason. The latest and deepest holes have been started with 18-in. casing, six reductions are then possible.

The casing is lowered and raised by a wire cable fall passing over the sheave at the top of the pile falls to the drum of the hoister. As the casing goes down, it is added to in 20-ft. lengths, the additional piece being supported by the fall while the men screw it into the coupling at the top of the line. Great care is taken with the joint, the coupling is extra long and an effort is made to have the pipe ends meet, so that in driving, the blows of the hammer will not be carried by the threads entirely.

The first material encountered is mud and silt and the large casing being very heavy, goes into it for the first 50 ft. very easily. When light driving ceases to have an effect, a 4-in. pipe is put down inside and connected with the pump by hose and a powerful stream of water forced through it, to stir up the material just below the bottom of the casing, the water returning inside the casing and bringing up the lighter material with it. The casing is at the same time pounded lightly by the pile-driver hammer which has a hole in its center through which the wash pipe passes.

PLATE 46.
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DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.

FIG. 1.—BREAKNECK MOUNTAIN.

FIG. 2.—ROCK AT TOP OF EAST TEST SHAFT.

The position of the bottom of the wash pipe is a matter for careful attention; it must be at or below the bottom of the casing to act upon the resisting material while, if it is too far below, the water of the jet escapes under the edge of the casing and no material is brought up. The position should vary with the material; in clay the wash pipe may go several feet below the casing without harm, while in gravel the water will escape in a few inches of space.

In the large casings, the space between wash pipe and casing is so great that the returning wash water has little velocity and brings up only the finer material, the pebbles remain and must be taken out from time to time by a bailer. This consists of a 10-ft. length of 8-in. or 6-in. pipe with foot-valve and a plunger which can be operated from the surface; it is lowered to the bottom, the plunger churned up and down, and it brings up sometimes a large quantity of gravel and cobble-stones. An 8-in. bailer will take in a 4-in. cobble. The bailer is an effectual way of removing material from large casing but has the disadvantage as compared with the wash pipe, that driving must stop while it is in use. With casing smaller than 6 in. the bailer cannot be used, but on the other hand, in a 6-in. or smaller casing, the space between the casing and wash pipe is small and the returning wash water has enough velocity to be effective in removing the material.

When the casing is stopped by cobbles too large for the bailer or when the bailer cannot be used, a chopping bit having edges in the shape of a cross or X is put onto the bottom of the drill rods, and used as in churn-drilling, the line of rods being repeatedly raised several feet by the hoister and dropped. The water jet is kept going at the same time, escaping through perforations at the end of the bit. This method is usually effective, if the stones are not too large, in breaking them up so that the wash water carries them off and the casing continues downward.

The action of the chopping bit gives some indication of the nature of the obstacle; if it is a moderate sized cobble, it breaks up after a time, chips from it wash up and the casing can be driven down; if a large stone is squarely in the way, the line of pipe rebounds upon hitting it and drilling into it is slow; if it is a nest of cobbles, chips come up freely, but the progress of the bit is slow and the casing usually does not go down at all.

In either of the latter cases, blasting is resorted to. The bit is removed and a line of 2½-in. or 4-in. pipe with its lower end open is washed down as far as possible into the hole made by the chopping bit in the sand and cobbles. The charge is put down in bundles of two or five sticks each, according as the 2½-in. or the 4-in. pipe is used, strung end for end on the exploding wire so that they will pass through the pipe; it is lowered by the wire, which is carefully measured off so as to surely reach the bottom. The pipe is then carefully lifted leaving the charge among the cobbles or resting on the boulder as the case may be; the casing, if necessary, is also raised so as to be at least 10 ft. above the dynamite. The charge is then set off by means of an electric battery and the casing immediately driven down again as far as possible.

The dynamite most used is 60% forcite though in extreme cases, a gelatine composed of 93% nitroglycerine and 7% guncotton has been used. A special exploder covered heavily with gutta-percha to bear the heavy water pressure has been used in the deep holes, as it has been found that a hydrostatic pressure of 500 ft. will force in the plug of an ordinary exploder, breaking the fuse bridge and rendering it inoperative. A number of exploders are always used, located at different places in the charge, to insure its going off. The explosives are used very freely in difficult ground, a usual charge is from four to twenty sticks of forcite and there is a record of one place where, in advancing 1 ft., eight shots and three failures of shots were made and 21 lb. of forcite and 76 lb. of gelatine used, the charge which finally made an end of the obstacle being made up of 10 lb. of nitrogelatine. At times the shots fail to go off, either from the fault of the exploders, from leakage of the electric current or from chilling of the dynamite in the water, and the process has to be repeated.

The effect of a blast is to shatter the stones close by and to push the material back, leaving a hole which must be taken advantage of at once by driving the casing before the stones fall in and fill it. If the obstacle has been a small boulder or a nest of a few cobbles, a single shot often disposes of it completely; if there are cobbles and boulders in large quantity, the advance is likely to be a few inches only and the processes of chopping and blasting must be repeated; if the boring comes squarely on top of a large

PLATE 47.
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DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.

FIG. 1.—BORING RIGS ON LINE OF AQUEDUCT TUNNEL UNDER THE HUDSON RIVER, LOOKING WEST TOWARDS STORM KING MOUNTAIN.

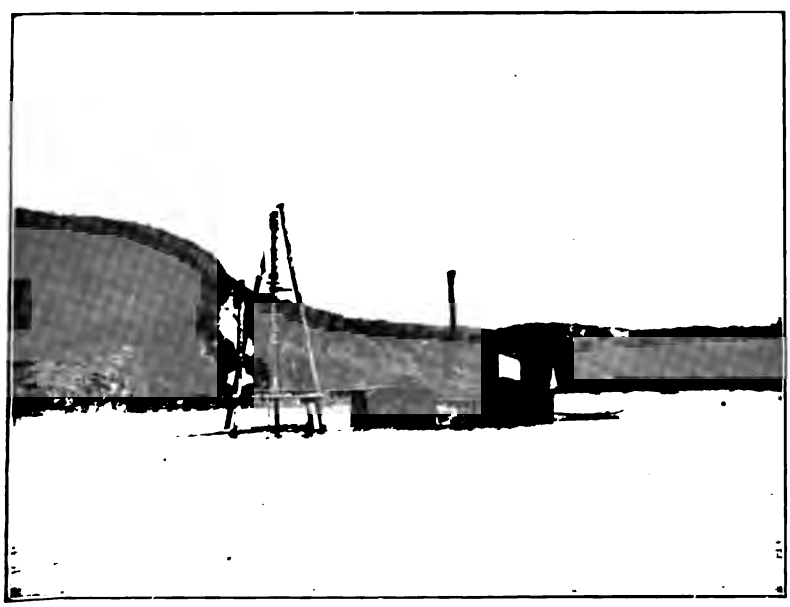

FIG. 2.—DIAMOND DRILLS ON PLATFORM SUPPORTED ON PILES, MAKING A BORING IN THE HUDSON RIVER.

boulder, blasting has but little effect and it becomes necessary to drill through it with a diamond bit, get dynamite down into the drill hole and so split it.

Much blasting in advance rather than hard driving is best for putting down the casing, for the necessity of drawing back at the time of shooting is vital and when the casing is driving hard there is always a possibility that it is deflecting on a boulder or being jammed between boulders into a condition which will make its withdrawal impossible. A blast within or near the end of a casing is likely to bend or broom its edges so as to stop the passage of smaller sized casing and may well cause the loss of the hole.

In raising casing, kinetic force was applied to some extent by means of a ring-shaped weight slipped over the top of the casing, then a clamp with projections fastened on and the weight brought up against it with a series of blows; also a very powerful jerk was applied by pulling steadily on the casing until the deck of the scow was almost under water, then releasing the friction on the engine and catching it again suddenly as the scow sprang up from the water. However, the power for lifting is far less than for driving, as there is nothing so effective as a falling pile-hammer, and, as the resistance to raising is almost as great as to driving, the lifting power of the pile-driver is usually the limiting condition to the depth that a line of casing may reach.

Sand and gravel tend to pack between the wash pipe and casing if not kept clear by a constant flow of the wash water; a few hours cessation of the water jet is enough in some kinds of material to permit sand to fill solidly between casing and pipe for several feet. For this reason, a reserve pump is kept on hand in case of breakdown and the wash pipe is removed when the gang quits each night. The same trouble occurs between casings at times when it is necessary to draw back for shooting. Inflowing sand lowers the effectiveness of the chopping bit by making a cushion over cobble stones and interferes also with blasting sometimes, by coming into the vacant space left when the casing is lifted, after the dynamite has been lowered to its desired position, and floating it up to a point where it will not be effective, or even where it will damage the casing. Many times it has been necessary to pull out a whole line of casing in order to free the wash pipe.

Efforts to lift wash pipe or casing when bound as just described or when jammed among cobble-stones produce strains which often pull it apart at joints; the wash rods sometimes jump apart in chopping. In such cases, if the break leaves a threaded end sticking up, it is sometimes possible to screw another pipe onto it but more often a recovering tap must be used. This is a cone shaped tool with cutting threads put down on the end of a line of pipe; it is manipulated until its end goes into the end of the broken casing, then it is turned until it has cut enough threads to have a secure hold on the casing and the whole thing is lifted. In the case of a small wash pipe inside of a large casing, it is very difficult to make the tap hit and if the break is below the bottom of the casing, the chances are still poorer; for such cases there is an outside recovering tap in which the cutting threads are on the inside of the cone. Many days are sometimes spent upon one operation.

A short piece of pipe, a shoe or a bit is almost hopeless of recovery and must be forced out of the way by any means possible, blasting being usually the most effective. The trouble is that such an object--and the same is true of a small-sized boulder—has a persistent tendency to remain in the hole below the casing made by the wash pipe and by blasting, or fall back into it, if once pushed aside, working down in advance of the casing, always in the way of the wash pipe and making the chopping bit ineffective.

Deflection of the casing upon the side of a boulder is another disaster to be guarded against. If driven any distance beyond the point of deflection, the casing tends to describe a curve, resistance is increased immensely and advance soon becomes impossible. While smaller casing and the flexible wash rods may be forced through the bend and continue until ledge is reached, the rotary motion of rods necessary for diamond drilling would be impossible, so whenever there is a suspicion that casing is going out of line, it is taken out, the bent piece at the bottom of the line removed and a blast put off at the point of difficulty. If the casing has been driven far beyond the point of deflection before the fact is discovered, so that it cannot be withdrawn, the case is very nearly hopeless, the only chance for continuing the boring being to cut the casing just above the bend, by means of a rotary cutting tool the blades of which are forced out into contact with the inside of the pipe by a taper. The straight part is then pulled up and the cut end recovered by

PLATE 48.
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DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.

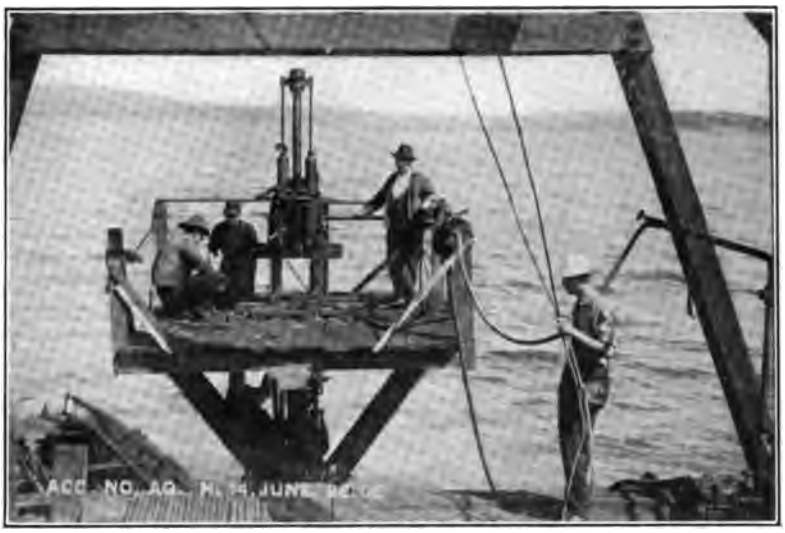

FIG. 1.—DIAMOND DRILL MOUNTED ON PLATFORM SUPPORTED BY CASING, MAKING BORING IN HUDSON RIVER.

FIG. 2.—DIAMOND DRILL ON PLATFORM WITH TENDER SCOW, MAKING BORING IN HUDSON RIVER.

fishing or blasted out of the way. This condition was encountered in one hole at a depth of 588 ft., five weeks' time and a great quantity of dynamite were used up in attempting to get the straight casing past the detached piece of pipe and the hole was finally abandoned.

A number of tools have been contrived to meet special cases; beside the recovering taps and cutter alluded to, *a gouge,* a solid cone-shaped tool, is used to force out the crumpled edges of a casing so that the smaller casing can pass through, and there is *a spear* for recovering short pieces of pipe; it passes through the pipe and then catches the bottom edge with its hinged barb.

The tall line of casing standing above the river bed is in danger of toppling over if once forced out of a vertical position. This has come about, in most cases, from collision by passing river craft; once the pile-driving scow, in a heavy storm, dragged its anchors and pushed the line over; and in one case, where a line of 8-in. casing was left standing unsupported in 80 ft. of water, it fell over of its own accord. In but one out of six cases has it been possible to erect the casing and continue the hole, as the casings were hopelessly crumpled at and below the river bed. In a modification of the original contract, it has been required that guard scows, flanking the pile-driving scow on each side, be maintained as a safeguard against further collisions by keeping the tug boats with their long lines of tows at a safe distance from the hole (see Plate 50, Fig. 1). On the later holes, the precaution has been taken of supporting the casing independently of the scow, by four anchors.

The work is otherwise interfered with by storms and large steamers passing at high speed. Large waves give the scow an up-and-down movement which makes work on the casing impossible. Days at a time are lost in this way during the autumn storms. With the approach of winter, the scows are driven from the river by floating ice, which would cut anchor lines and carry everything before it. About five months are lost in the winter time.

In leaving unfinished holes for the winter, the casing is unscrewed and removed to a depth that will be safe for passing vessels. When work is resumed in the spring, the services of a diver are needed in reconnecting the casing.

A surface of firm rock being reached which resists chopping and blasting, it becomes necessary to drill into it with a diamond

bit either to prove that it is ledge or, if a boulder, to give effect to a blast. A diamond drill machine must have an immovable support, consequently it cannot be worked on the scow, which goes up and down with the waves. On the first holes four piles were driven about the hole and a platform built on them and the casing with some bracing and anchor lines for lateral support (see Plate 47, Fig. 2). This structure proved an encumbrance when the rock was proved to be a boulder, and washing and pile driving had to be resumed with the scow. Later was adopted the device now in use of a small platform supported on wooden brackets clamped to the casing, easily attached or removed (see Plate 48, Fig. 1). The casing is held in place by four anchor lines attached at about the surface of the river. The platform is just large enough to carry the drilling machine and to give the men working space; the boiler, the pump and all other equipment are kept on a tender scow anchored close by, the boiler being connected up with the drill by a flexible hose. The pile-driving scow serves as a tender while the boring is in boulders, as its pile-driving and hoisting facilities will be needed again for sinking casing when the boulder has been broken up. When there is proof that bed rock has been reached the large scow is released for use elsewhere and a small tender is substituted. This is a scow about 30 ft. by 20 ft. just large enough to carry a boiler, a supply of coal, the pump, and the smaller equipment necessary; it has an extension frame projecting from one end which reaches over the drilling platform to the hole and carries a pulley for hoisting and lowering the drill rods (see Plate 48, Fig. 2).

If it is believed that the boring is on a boulder, not much time is spent in preparation for drilling for there is not likely to be much of it, but when it seems probable that bed rock is reached great pains are taken to get the casing seated so that sand shall not wash under its edge from outside, as that is prohibitive to drilling operations. To this end the chopping bit is worked on the rock until a hole is made into which the 2½-in. casing will settle for several inches, then cement is dropped in to form a grout and seal all openings between casing and rock.

The drilling itself does not differ from that carried on under other conditions and is, of course, a familiar operation. The bit used is $2\frac{1}{16}$ in. in diameter, and brings up a 1½-in. core. Usually

PLATE 49.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON RIVER CROSSING OF CATSKILL AQUEDUCT.

FIG. 1.—WEST TEST SHAFT, SHOWING TRESTLE FOR CONVEYING EXCAVATED MATERIAL TO THE RIVER.

FIG. 2.—EAST TEST SHAFT, SHOWING EQUIPMENT WHEN WORK WAS BEING DONE BY THE CRANFORD CO.

four diamonds are set in the outer edge and four in the inner edge, about 12 carats of stones in all. Above the bit is a 10-ft. core barrel of the same diameter as the bit, into which the core passes and is held by a spring collar; the length of this barrel of course limits the length of drilling without pulling out the rods, but usually the diamonds need resetting before the core barrel is full. The rods are $1\frac{7}{8}$ in. in diameter with a flush joint, the hole through them is $1\frac{1}{2}$ in., except at the unions where it is only $\frac{3}{4}$ in. They are in 10-ft. lengths, but in being taken out are usually broken at second joints only. The drilling machine has a capacity for 1 000 ft. It consists of a geared spindle driven by a steam cylinder which rotates the line of rods and feeds them down the hole. It has also hydraulic cylinders for producing and regulating the pressure of the bit against the rock; in our work the weight of the great length of rods is more than sufficient, and the hydraulic cylinders are used, when at all, to relieve the pressure somewhat. Water is forced through the rods to cool the bit and wash away the cuttings; it is of the greatest importance and the action of the pump and the return of the wash water are carefully watched by the drill runner as seams are sometimes encountered through which the water escapes, allowing the cuttings to collect about the core barrel until it is wedged tight, or leaving the bit uncooled, in which case such a heat is generated as to destroy the diamonds. It is necessary to take out the bit after drilling from 10 to 20 ft., to reset the diamonds and clear out the core barrel; the removal and return of a such a length of rods, unscrewing each 20-ft. length, takes up a considerable part of the time.

A diamond is sometimes torn out of its setting at a seam in the rock or from breaking up of the core; it at once becomes a menace to the other diamonds and as soon as the accident is discovered, work is stopped until the diamond is recovered. This is often accomplished with a blank bit filled with soft wax to which the diamond adheres. A bit is sometimes twisted off and sometimes pieces of metal get into the hole. In such cases, if recovering taps and wax bits fail, it is sometimes necessary to fill the hole with grout above the obstacle and start at the top of the rock with a larger sized bit and ream out the hole to a point below the obstacle which then, if all goes well, is brought up embedded in the core.

The core is carefully preserved in slotted boxes which keep it in the order of its occurrence. It gives good indication of the character of the rock, as seams and decomposed rock are apparent, as well as the mineral components.

It will be seen that a high order of judgment and energy are required in the boring foreman, especially at the greater depths among the boulders. Not being able to see the conditions, his imagination and powers of deduction are taxed quite as a physician's are in diagnosis, and his perseverance above all. Considering the great difficulties and the new conditions we believe that good results have been obtained.

The force on each scow consists of a foreman and three or four men; this foreman is also a runner when it comes to diamond drill work. There is also a general superintendent. Wash boring can be done only by daylight, so, in general, there is but one shift per day; on diamond drill work it is usual to work two shifts daily.

Of fifteen river holes, six reached rock it is believed; of the other nine, two were knocked over by passing vessels, one by its own scow, one fell over of its own weight, two were abandoned because of conditions at their bottoms, two were discontinued because supplanted in usefulness by other holes, and one is still in progress. Figures of average progress are not of great value as of course in the shallower holes speed was much greater and in the deep holes less. In the progress on diamond drilling the time used in setting the platform and other preparation is included and, as in several cases the distance drilled was small, this affects the result largely.

Number of borings	15
Aggregate length in water	767 ft.
" " " earth	4 656 ft.
" " " bed rock	202 ft.
Average progress per shift in earth	2.3 ft.
" " " " " bed rock	2.2 ft.
Average progress per shift in water, earth and bed rock	2.7 ft.
Average progress per shift in earth in boring No. 24, 749 ft. deep	1.6 ft.
Average progress per shift in earth and water boring No. 24, 749 ft. deep	1.8 ft.

Test Shafts.

At the close of the season of 1906, it was determined to supplement the vertical river hole method of determining the rock profile by sinking a test shaft on each side of the river from which further investigation could be made by horizontal or inclined test borings. The shafts, while primarily intended for exploring the site for a crossing, were designed of such size and shape and were located at such points that they could be incorporated as a part of the great waterway if the explorations could be brought to a successful and favorable conclusion.

Accordingly, early in 1907, bids were called for on an agreement (Agreement No. 37) for the construction of test shafts to Elevation —650 and the driving of inclined borings. The Cranford Company of Brooklyn was the lowest of four bidders and was awarded the work on February 23d. Actual excavation of the West Test Shaft was begun March 7th, and of the East Test Shaft, April 6th. The contractor suspended work December 7th, 1907, with the West Shaft excavated to Elevation —226 and the East Shaft to Elevation —249. No inclined borings had been made.

The continuance of the work under another agreement was contemplated, but it was finally deemed advisable to continue the exploration by day labor under the supervision of the Board's engineers. The work was resumed at the West Shaft in October and at the East Shaft in November, 1908. Actual work on the bottom was delayed by changes in plant and by unwatering of the shafts until March 3d at the East and until May 30th, 1909, at the West Shaft. In such manner the work has been continued to the present time.

Under the agreement with the Cranford Company the West Shaft was started 80 ft. west of the river's edge and 40 ft. above it; the East Shaft was located 140 ft. from the water and 31.5 ft. in elevation. The distance from center to center was 3 022 ft. Both sites were comparatively easy of access and presented no unusual difficulties. Permission for spoiling directly into the river had been obtained from the War Department and from the owners of water rights (see Plate 49, Fig. 1). Elevation —185 was selected as a point at which shore headings should be excavated for connection with the future aqueduct, and marked a line of division

between different types of excavation. The West Shaft was excavated rectangular in section, 11 ft. 4 in. by 18 ft. 0 in., to the depth of the shore heading, as that much of it was to be used merely for construction. The East Shaft was designed as a pump shaft for unwatering the siphon and its upper part was made circular in section, 17 ft. 8 in. in diameter. Below —185 both shafts were circular and 16 ft. 10 in. in diameter. The shore headings were excavated to a depth of 25 ft.

At the base of Breakneck Mountain along the New York Central tracks, the Cranford Company assembled a compressor plant consisting of two 125-h.p. Coatesville boilers and two Sullivan 20 in. by 22 in. by 14 in. by 24 in. straight-line two-stage air compressors with a capacity each of 1 160 cu. ft. of free air per minute. For hoisting muck and handling materials in the shaft a 40-h.p. National hoisting engine, supplied with steam by a 50-h.p. locomotive boiler, operated a bull-wheel, stiff-leg derrick (see Plate 49, Fig. 2). Sullivan UH 3⅝-in. differential drills were used. A similar plant was installed at the West Shaft, except that only one compressor of the same type supplied air and Sullivan UF-2 3¼-in. drills were employed. The shafts were lighted by electricity produced by dynamos in each plant.

The guaranteed progress was 4½ ft. of rectangular and 4 ft. of circular shaft per day, including timbering with 10 in. by 10 in. timbers forming a 9 ft. 8 in. by 9 ft. 10 in. cageway in circular and 9 ft. 8 in. by 16 ft. 4 in. in rectangular shaft. The average progress actually made, excluding time for timbering, Sundays and holidays, was as follows:

Rectangular—18 ft. by 11 ft. 4 in...2.24 ft. per 24-hr. day.
Circular—17 ft. 8 in. in diameter....1.93 " " " "
Circular—16 ft. 10 in. in diameter...1.25 " " " "

For elapsed time, the West Shaft had an average progress of 30 ft. per calendar month and the East Shaft, 35 ft. per month.

Bed rock was encountered just below the surface of the East Shaft and at a depth of 7 ft. at the West Shaft; therefore, these figures are for excavation in granitic gneiss. The shafts were timbered to the top of the shore headings.

When work was resumed on the shafts by day labor under the supervision of the Board's engineers, the Cranford Company plant, which still occupied the sites, was considered inadequate for sinking

PLATE 50.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.

FIG. 1.—WEST TEST SHAFT, SHOWING HEAD FRAME INSTALLED BY THE BOARD OF WATER SUPPLY AND SCOW ON RIVER BORING WITH ITS GUARD SCOWS.

FIG. 2.—DIAMOND DRILL IN ITS CHAMBER AT THE WEST TEST SHAFT MAKING AN INCLINED BORING

to depths to which it might be necessary to go. The derricks were removed, concrete collars set around the mouths of the shafts to prevent the inflow of any surface water and approved timber head frames were erected suitable for hoisting cages when tunnelling should begin (see Plate 50, Fig. 1, and Plate 51). J. S. Mundy, 16 in. by 20 in. double-cylinder, single-drum, double-geared mine hoists were procured and set up. On the east side, steam was supplied by two new 100-h.p. Ames boilers and at the West Shaft the old compressor plant boilers were moved to the shaft to give power to the engine. The old National engines are used as auxiliary hoists.

The original compressor plant at the East Shaft was enlarged by the addition of two 150-h.p. Erie boilers (a third is now being set up) and by the Sullivan straight-line compressor from the west side of the river. For the West Shaft an entirely new compressor plant, consisting of three Babcock-Wilcox 130-h.p. water-tube boilers and two 16 in. by 28 in. by 25½ in. by 16½ in. by 16 in. Ingersoll-Rand type HH3, cross-compound air compressors, having capacity each of 1 392 cu. ft. of free air per minute, was established between the river and the West Shore Railroad 2 500 ft. north of the shaft. This site was chosen for convenience in receiving coal. Air is delivered on both sides of the river through 6-in. pipe lines. Sullivan UH 3⅜-in. drills on tripods were retained in use at the East Shaft while a combination of Ingersoll-Rand 3½-in. and Sullivan UF-2 3½-in. drills on shaft bars have prepared the rounds for shooting on the west side.

The shafts were unwatered by pumping and bailing, the timbering was examined and some added to bring it nearer to the bottom. When excavation began, the first work was expended in the construction of diamond drill chambers. This required the removal of about 250 cu. yd. at the East Shaft to accommodate drill machines and pumps. In vertical section, the chambers were made fanlike to permit the drawing of rods in 30-ft. lengths from holes drilled on slopes anywhere from 20° to 45° below the horizontal. In the West Shaft where part of the shaft itself behind the timbers was utilized by making the wedge-like chamber intersect the shaft along one side and project into the rock on both ends, the excavation was only 135 yards.

Sinking operations were resumed upon completion of the chambers. Assuming that the shafts would be driven to Elevation —1 200, and presupposing a flow of 1 000 gal. per minute into the workings on each side of the river, for pumping purposes this distance was divided into three lifts of 400 ft. each and around Elevation —400 and —800 where the rock was most suitable, station pump chambers capable of holding three 16 in. by 7 in. by 18 in. Jeanesville duplex plunger pumps were excavated. At present these chambers are provided with only a sufficient number of pumps to take care of the existing flow; the other pumps will be added as needed.

For security in working, the shafts are timbered with 8 in. by 8 in. yellow pine timber sets with a clear way of 9 ft. 8 in. by 9 ft. 10 in. placed on 5½-ft. centers and lagged between with 2-in. pine plank. From 50 to 100 ft. of shaft are timbered at a time as the character of the rock may allow. The timbers are supported and built up from four 10 in. by 12 in. white oak bearing timbers which rest in niches cut in the shaft walls. Behind the timbers for about 5 ft. above the bearing logs, the space is packed with cordwood, and where the wetness of the shaft demands, a concrete ring is deposited on top of the packing to catch the water. A small sump in the ring and small pump sufficed to lift the water to the station chamber above until the next chamber below was finished, then the water was piped down to the station pumps.

Ventilation of the workings is effected with considerable efficiency in the East Shaft by means of a 2-in. tongued and grooved board-lined compartment built in one corner of the timbers 1 ft. 8 in. by 4 ft. inside dimensions in which a current of air is kept rising by the exhaust from the pumps which in the upper chamber are operated on part steam and part air. At the West Shaft, a steam driven 30-in. fan exhausting through a 12-in. diameter galvanized spiral riveted slip-joint pipe performs a similar service.

On September 14, 1910, the East Shaft had reached Elevation —963 with timber to —930 and the West Shaft —865 being timbered to —822. The average progress including all attendant operations reckoned from the dates of starting actual excavation has been 38.9 ft. per month in the East Shaft and 41.2 ft. per month in the West Shaft. However, a maximum progress of 65 ft. sunk in one calendar month has been reached in the East and 69 ft. in

the West Shaft. The difference in average progress is easily accounted for by the larger quantities of water handled at the East Shaft.

In the depths sunk by the Cranford Company the maximum inflow at the East Shaft was 5 gal. per minute and at the West Shaft 12 gal. per minute at such times when there was no surface water taken in at the mouth of the shafts. To date the maximum flow at the West Shaft has been only 30 gal. per minute. Water bearing seams yielding 20 gal. per minute were struck in the East Shaft at Elevation —367 and to some distance below the first pump chamber the rock continued very wet. In the pump chamber itself a flow of 100 gal. per minute made the work slow and laborious. All the while, the wettest diamond drill boring was being driven and at one time for a short period, added 180 gal. per minute to the shaft water when the hole was open. At such time, the maximum quantity of water pumped to the surface was about 350 gal. per minute. With the closure of the drill holes and a somewhat lower flow into the shaft there is at present only 140 gal. per minute to be handled. Altogether, it seems rather remarkable that these shafts can be sunk within so short a distance of a large body of water and be so dry.

A phenomenon which is peculiar and disconcerting to the workmen in the shafts is that of popping rock. Without warning there will be a loud report like a pistol shot and a piece of rock from the wall will fly into or across the shaft. Usually the fragment is small and does no damage, but at times has caused injuries of minor nature. This popping may occur from rock surfaces which have been uncovered several days. It has not been very frequent and was first noticed in the West Shaft at Elevation —450. Prof. W. O. Crosby has explained the phenomenon as an explosion resulting from the local relief from mechanical pressure to which the rock is subjected by the wedge like structure of the granite underlying the river. He says:

"The relief will, normally, find expression either in scaling or in the development of cracks or rifts, which, tending to be parallel with the east and west sides of the shafts, will rather seldom be subject to direct observation. Every such snapping or sudden giving way or rifting of the granite gives rise to a miniature earthquake.

"I may add that this is a fairly common happening in mines and quarries. Often in quarries the compressive strain is measured by an appreciable stretching of the rock when released, so that it would be impossible to force a block into the space which it formerly occupied. This phenomenon of spontaneous snapping and rifting has recently been described as occurring in some of the deep Lake Superior copper mines.

"That it was not observed nearer the surface in the Hudson River shafts is probably due to the relief long since afforded by the erosion of the gorge of the Hudson. It should not be regarded as jeopardizing appreciably the security of either shafts or tunnel and it is evident that we have here a powerful agent tending to tighten and close up seams in the granite."

The information collected from the sinking of the test shafts themselves is in every respect favorable to the construction of a bed rock tunnel crossing. The rock passed through has been granitic gneiss of varying hardness and interspersed with diorite but always of a quality which could scarcely be improved upon for the construction proposed. The water inflow has not been excessive nor even a very great hindrance to prosecution of the work. As already noted, the popping rock is ephemeral and of no consequence as affecting the completed waterway. The shafts as much as could have been expected on their part have given satisfactory evidence of the feasibility of a crossing in the granite beneath the Hudson.

Inclined Borings.

In the earlier stages of exploration at Storm King, very little was attempted in the way of borings driven from the shore to gain information under the river. While Hole No. 11 was drilled vertically into the bank 30 ft. from the west shore to a depth of 219 ft., Hole No. 12 inclined 32° 24′ from the vertical to a depth of 221 ft. on the east side and Hole No. 13, 24° 4′ from the vertical, started 25 ft. from the water on the west and continued for 566 ft., these holes were all rather a preliminary adjunct to the sinking of the test shafts than any investigation of the bed-rock channel. These borings had all been started by March, 1907.

The failure to sink the test shafts to the depths required for inclined borings under the original agreement with the contractor and the time lost in resuming work afterward, made urgent the trial for information by borings under the river. It was decided to

PLATE 51.
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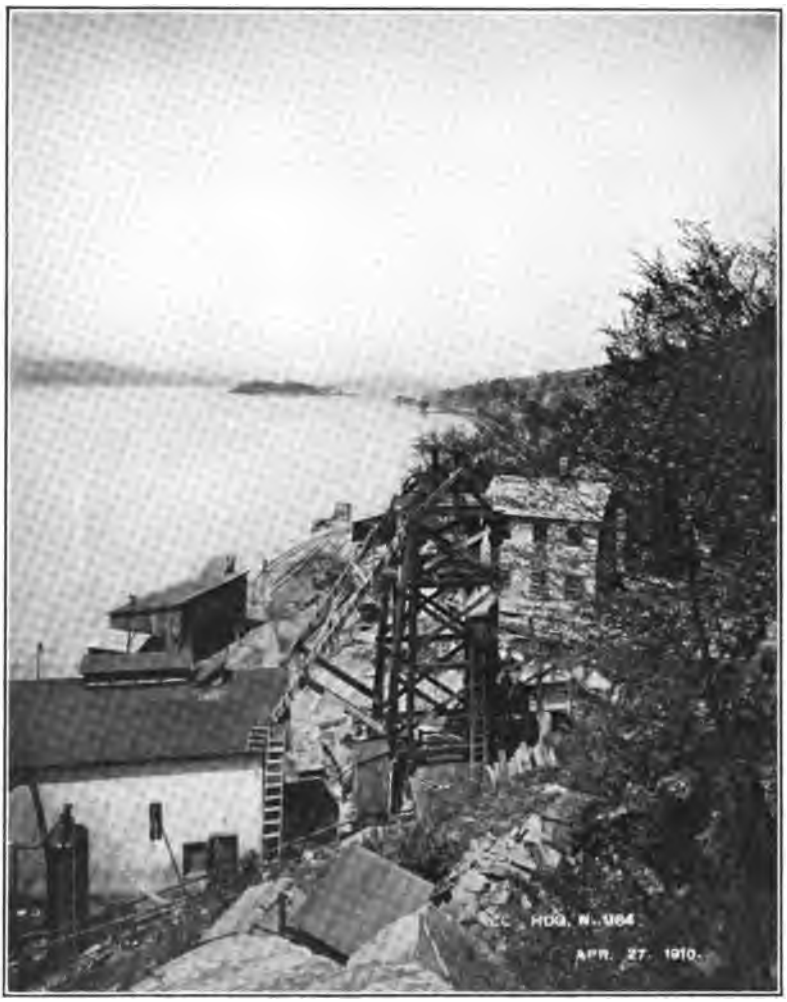
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.



EAST TEST SHAFT, SHOWING THE EQUIPMENT INSTALLED BY THE BOARD OF WATER SUPPLY.

excavate the drill chambers at the bottoms of the shafts as they then existed, and from them to cross the valley by borings entirely in rock (see Plate 43) and by the core obtained to see if the fault zone feared by the geologists existed, or if any other unsuitable formation should be lurking to defeat the crossing. Meanwhile, work on the vertical borings in the river would be continued. The engineers did not doubt the feasibility but lacked proofs that would appeal to the public. The latter, not always imbued with an engineering patience began to be skeptical of this tunnel. The daily papers had imaginary holes in the river 1 000 ft. deep which did not touch rock and cartoons declared the only way to cross the Hudson was to carry the water across in boats or shoot it across by nozzle to a tank on the other side. Proofs were being demanded.

Looking in this new direction, work was hurried on drill chambers at the bottoms of the shafts. Agreement No. 74 was awarded to Sprague & Henwood, of Scranton, Pennsylvania. To quote from the agreement itself:

"The purpose of this agreement is to make two inclined borings, one from each side of the Hudson River, in order to determine the character and continuity of the rock beneath it on the line of the proposed aqueduct crossing. It is intended to conduct these drilling operations so that the holes will pass each other at a point near the center of the river and lie within a prescribed zone."

The zone referred to was the area bounded on the lower side by two circular arcs of 11 460 ft. radius (½ degree) and on the upper side by two arcs of 3 820 ft. radius (1½ degrees), the curves in pairs being tangent at the drill chamber to each other and to straight lines drawn from the supposed beginnings of the holes to a point at the center of Elevation — 1 650. The arcs intersected at the center at about Elevation —1 130 and —1 440 (see Plate 52). This zone was designed with a view to keeping the boring in rock by following in general the bed-rock pofile and at the same time allowing the borings to cross at as high an elevation as consistent with safety to them. To reach the center of the river with borings lying wholly within this zone required them to be from 1 720 to 1 880 ft. long. The claim was made by some, experienced in diamond drill work of this character, that it was possible to control in one way or another, the direction of a diamond drill boring. As an in-

ducement to performance of the work, in accordance with the specifications, the bid was made under two items, as follows:

Item No. 1.—For drilling the first 900 ft. of any hole or for drilling the remainder beyond 900 ft. of any hole not included in item No. 2, the sum of $6.50 per lin. ft.

Item No. 2.—For drilling the remainder beyond 900 ft. of any hole which either terminates within the ordered zone or passes in solid rock about the ordered zone, a hole from the opposite side of the river, the sum of $10 per lin. ft.

The prices inserted are the agreement prices with Sprague & Henwood.

The East Shaft chamber was ready in May, 1909, and Hole No. 1/A-74 was started June 1st. The machine, Sullivan diamond B drill (see Plate 50, Fig. 2), rated for 3 000 ft. of hole, was set for an angle of 43° below the horizontal, that being practically the slope of the tangent to the zone. The agreement called for a hole starting not less than $2\frac{1}{16}$ in. in diameter. Sprague & Henwood decided that the safest way to get the holes to such depths, was by two successive reductions in size. The holes were started with $2\frac{1}{2}$-in. bits, reduced to 2 in. and later to $1\frac{3}{8}$ in. As a precaution against a heavy flow of water, the drilling was carried on through a 3-in. gate valve attached to a 3-in. pipe grouted in the rock. To seat the pipe the first 7 ft. of the hole was bored with a 4-in. bit.

The drillers desired to drive the first several hundred feet as nearly straight as possible on the line set, so that great care was taken with the drilling apparatus to produce that result. The $2\frac{1}{2}$-in. bit was set as usual with eight diamonds, four to cut hole, four to cut core and all to cut ahead, but was set to as small a clearance as possible. The diamonds projected only $\frac{1}{64}$ in. outside. The bit, shell, core-barrel and 60 ft. of rods immediately following were all the same size, actually $2\frac{1}{16}$ in. in diameter. These rods were termed guide rods. Behind the guide rods, 2-in. rods were coupled on as needed. Despite all care, a survey made when the hole was at a depth of 177 ft. showed that the boring was turning downward. The guide rods were taken off so that the sagging of the smaller rods behind the core barrel would force the bit upward. Another test made at a depth of 280 ft. gave proof that the rods were holding to a straight line and with perhaps a slight upward tendency.

The hole continued at approximately this inclination, which was a trifle less than the initial slope, to a depth of 641 ft.

Here the reduction was made to a 2-in. bit. Here, also, whether by means of forcing the rods, as claimed, or by chance, began the first upward turn of the hole. This upward movement seemed to be increased by the use of a tapered core barrel along with a forcing of the rods until at a depth of 1 398 ft. the survey showed the inclination at that point to be about 37° 20′. Then began another downward curve to the end.

A small flow of water was encountered in Hole 1/A-74 at a very small depth. This gradually increased as drilling progressed until at the time of the first reduction in size the flow from the open hole was 50 gal. per minute. At a depth of 734 ft. the flow had reached 90 gal. per minute and was hindering the work.

A careless drill runner nearly ruined the hole at this point as a direct result of the back pressure exerted by the water. He did not keep his pump going hard enough to force water through the rods, and the bit was burned fast in the rock. The rods were detached from the bit, the 2½-in. hole was extended to 734.3 ft. by reaming and the 2-in. bit, or what was left of it, was recovered as core with the steel and diamonds fused into the rock.

In order to shut off the water, 2½-in. flush-joint casing with several diamond chips set into its lower end was placed in the hole. It was turned by the machine like rods until the bottom was burned fast to the rock as the bit had been. The water flow was reduced to 5 gal. per minute, but did not long remain so small. By the time 1 085 ft. had been drilled the open hole was sending a solid stream of water, 180 gal. per minute, 10 ft. from its mouth into the chamber. With this flow the last hundred feet of rods need not be pulled from the hole when core was being recovered; they slid out. No other advantage could be credited to the water which made drilling unpleasant work until the hole was again cased at a depth of 1 234 ft. with 2-in. flush-joint casing and again reduced in size. The water flow in this hole was one of the deciding elements for reduction in size. The quantity was lessened to 10 gal. at this final casing and did not increase beyond 70 gal. per minute, which was judged to be a limit of flow under the existing head from the now long hole.

At a depth of 1 834 ft. the bit was again burned fast. Over two months' work failed to remove it. Diamonds, collectively valued at over $1 500, and about 600 ft. of small rods were lost. Hole No. 1/A-74 had not entered the ordered zone and did not quite reach the center of the river.

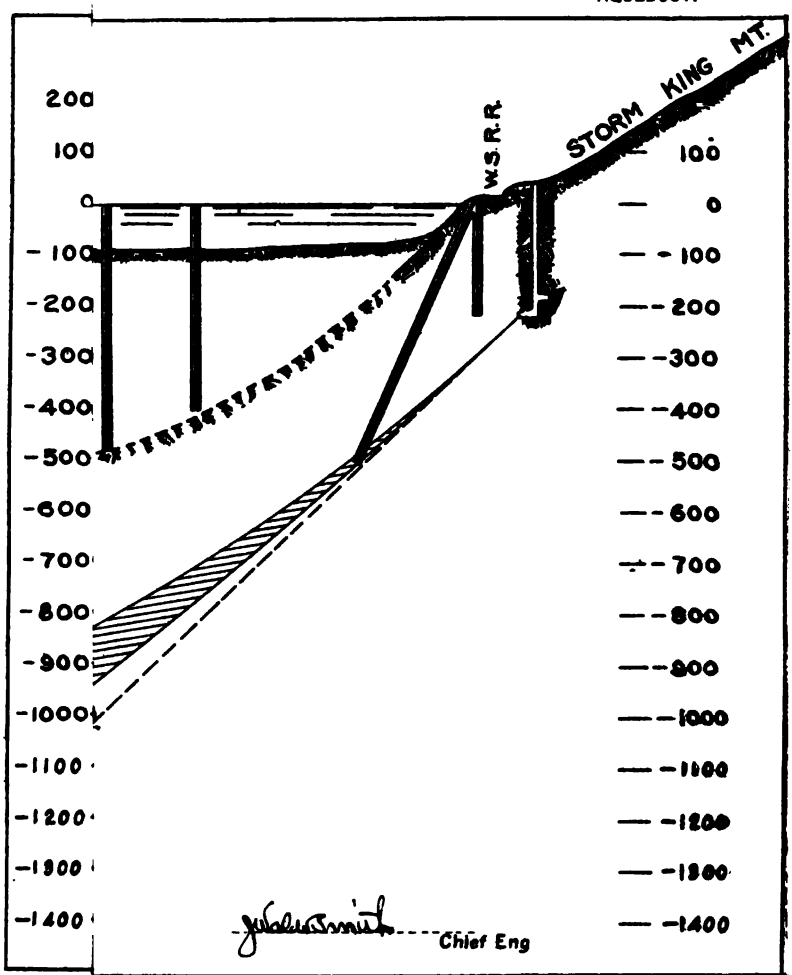
The second hole started from the West Shaft at an angle of 38° with the horizontal (on line with the bottom of the zone) was drilled with more success. The maximum flow of water from the open hole was only 5 gal. per minute, so that no casing was required. The general tendency of the hole was downward, there being only one place from 1 417 to 1 477 ft. where the survey showed an inclination above that at which the hole had been started. It was driven, however, to a depth of 2 051.6 ft., enough to place the end horizontally past the end of the first hole though 80 ft. below it (see Plate 43).

Drilling in both holes was carried on by three eight-hour shifts, consisting each of one drill runner and one or two helpers, according to conditions. When the rods had to be pushed into the hole, as they did against the flow of water in Hole No. 1/A-74, and as they did later on account of the flatter slope of the holes of Agreement No. 77, two helpers were necessary. One diamond setter also in charge of the work on each side of the river was sufficient to keep the bits in repair.

With the completion of Hole No. 2/A-74, March 31st, 1910, the proofs lay in two stacks of core boxes, that rock of the same general quality as that encountered in the shafts lay all the way beneath the Hudson. The core showed no evidences of a fault zone, and had been recovered with such regularity as to make impossible the passing of unsuitable rock without its presence being detected. The drilling, too, indicated no unfavorable condition.

As soon as possible, under Agreement No. 77, a second set of holes were started from the same chambers and in line for a point at the center 900 ft. beneath the surface. Sprague & Henwood were again the successful bidders. In the same general method these holes were drilled past the center of the river crossing at Elevation —955. Only the two larger sizes of rods were used, since the depths required were only about 1 600 ft. The same care was used in setting the bits for smaller clearance to hold the borings to line, but no attempts were made to curve the holes upward. As with the

PLATE 52.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.



R AGREEMENT 74. (THE FIRST SET OF BORINGS.)

first holes, these also tended to increase in slope. Although the borings of Agreement No. 77 skirted closely the points now known in the surface of the bed-rock channel, they continued wholly in rock and produced core equal in quality and proportionate quantity to that obtained from the lower holes. There was no indication of open seams and no intersection with a bed-rock surface. As before, the water-bearing seams were more numerous on the east side, Hole No. 1/A-77 producing 120 gal. at the finish. Although this hole traversed higher ground than the former one put out from the East Shaft, and therefore might be expected to be wetter, the inflow of water into it was considerably less.

Sprague & Henwood deserve more than a word of commendation for the patience under discouraging conditions, the skill and the rapidity with which they successfully made these, to this region, unprecedented long borings. Their success is, in large measure, due to their long experience, their faculty of adapting methods to conditions and their unfailing persistence.

The results of the inclined-boring tests are given in the following table:

TABULATED HISTORY OF INCLINED BORINGS ACROSS THE HUDSON CHANNEL.

	First Set.		Second Set.	
	Hole No. 1/A74 East.	Hole No. 2/A74 West.	Hole No. 1/A77 East.	Hole No. 2/A77 West.
Work started	May 24, '09	July 20, '09	Mar. 29, '10	
Drilling began	June 1, '09	July 29, '09	Apr. 5, '10	Apr. 20, '10
Drilling finished	Dec. 15, '09	Mar. 31, '10	Aug. 4, '10	Aug. 25, '10
Elapsed time of drilling—days	198	214	122	127
Working time, days of three 8-hr. shifts	167	198	85	107
Actual drilling time—8-hr. shifts	331	429	214	279
Feet drilled per actual drilling shift	5.54	4.78	7.73	5.93
Feet of 4-in. hole and percentage 3-in. core recovered	7.2-47%	8.0-75%	8.5-78%	7.1-76%
Feet of 2¾-in. hole and percentage 2-in. core recovered	688.8-79%	711.8-91%	715.5-84%	772.4-88%
Feet of 2 1/16-in. hole and percentage 1⅝-in. core recovered	593.0-41%	759.5-76%	927.4-48%	872.6-68%
Feet of 1⅞-in. hole and percentage 1⅜-in. core recovered	600.0-27%	572.8-22%		
Total depth of hole	1 884.0	2 051.6	1 651.4	1 652.1
Total core recovered and percentage of depth drilled	1 018.2-55%	1 360.3-66%	1 052.1-64%	1 245.0-75%
Elevation of top of hole	—281.0	—251.2	—279.7	—245.8
Elevation of bottom of hole	—1 482	—1 564	—965	—961
Inclination below horizontal at top	43° 0′	38° 0′	22° 53	23° 40′
Inclination below horizontal at bottom	38° 55′	44° 47′	23° 35′	25° 55′
Maximum variation of inclination	7° 15′	7° 20′	2° 52′	2° 27′
Maximum water flow from open hole in gallons per minute	180	5	120	25
2¾-in. flush joint casing used—feet	735	none	724	723
2-in. flush joint casing used—feet	499	none	none	none

Mention has been made from time to time of a survey of the inclined holes. The form of agreements under which the work was done required a knowledge of the direction taken by the borings in order to determine whether or not the bits were traversing the ordered zones. Two methods, known as the hydrofluoric acid test and the pressure gage test, were employed. A brief description of each will be given.

The hydrofluoric acid test for inclination is based on the power of hydrofluoric acid to etch glass and the principle whereby the surface of a liquid at rest under the action of gravity assumes a horizontal position. At various known depths along the boring to be surveyed readings for the inclination are obtained from a horizontal-etched line on a glass tube whose axis is parallel with the direction of the hole. These inclinations constitute a series of tangents to a compound curve which is the line of the hole itself. Of course, this method gives a determination only, as it were, in dip and not at all in strike.

An ordinary homeopathic pill vial, $\frac{7}{8}$ in. outside diameter, $\frac{15}{16}$ in. inside diameter and $4\frac{5}{8}$ in. long, containing a solution of nine parts by volume of water and one part by volume of hydrofluoric acid, is placed in a water-tight steel shell, about a foot long, which is the same diameter as the rods in use and is bored to exactly hold the bottle. The shell or tester is coupled to the rods and lowered into the hole. During the time required for lowering the rods no definite line is etched, because the rods in turning apply the acid to all sides of the tube and because the solution is made weak in order to reduce the action as much as possible. When the required depth is reached the rods are clamped and allowed to rest long enough for the acid to do its work. At great depths the period at rest required to give a well-defined line is about an hour. The rod is rapidly withdrawn and the acid emptied from the recovered tube.

For the survey of these holes, the angles were read by placing the record tube in a machine constructed for the purpose. The tube was clamped to a revolving pivot in such manner that the etched line and the side of the bottle could in turn be sighted in parallel with a straight edge which is the diameter of a graduated semi-circle protractor. A reading was taken of the position of a needle which was rigidly connected with the pivot and played over

the graduated arc. The difference in readings gave the observed angle. Owing to the effect of capillary attraction on the acid solution the observed angle was not the true angle. A minus correction varying from 4° for a reading of 26° 24′ to 8° for a reading of 52° 05′ had to be applied to obtain the true slope. A correction diagram was prepared by taking readings on tubes exposed to known slopes. The final accepted angle was an average of 24 readings made by two independent observers. Tests were made not more than a hundred feet apart.

The hydrofluoric acid test was the most used method of making surveys; but it had one objection—one erroneous reading changed the position of all the hole below it. It is apparent, therefore, why the precautions above described were taken to eliminate the danger of such an error.

The other method tried was that of a recording pressure gage, designed and made by Dr. Herbert T. Kalmus and Mr. Gilbert N. Lewis, of the Massachusetts Institute of Technology. The gage was made so that it could be inserted in a hole and lowered to the desired point by means of a pliable wire cable. From the flow of water, the holes were always full and the object was to measure the static head at any point, preferably near the bottom, as the location of the ends of the holes was most important. Accordingly, the gage was designed for only heavy pressures.

The gage consisted of a flat steel tube with a certain resisting power which was placed in the lower end of the inch tube encasing the whole gage, so that it could be exposed to the external pressure of the water. To the top of the flat tube and in a water-tight compartment of the casing tube, was connected a glass capillary tube which opened into a small cup. The flat steel tube and the glass tube were filled with mercury when the instrument was ready for a test.

Now, when the gage was subjected to pressure the steel tube was compressed and forced mercury into the cup from which it could not return when the pressure was removed. Then by simply reading the height of mercury in the tube, the pressure to which the gage had been subjected was known. The instrument, of course, had been calibrated by applying known pressures and marking the heights of mercury.

The principle of obtaining the vertical distance of a point at known depth below the top of the hole was excellent, but the machine did not always work well under the conditions which obtained. The gage recorded only the highest pressure. and it was practically impossible to lower the gage so that higher pressures than that of the static head would not be recorded. The movement of the gage through the water affected the pressure. All sorts of schemes were tried to offset the disadvantage. Even when the pressure was allowed to reach the flat steel tube only through a 3-ft. capillary tube, impact pressures were sometimes recorded, in which cases the machine would not check either itself or the survey by the hydrofluoric acid test, and no credence could be placed on the results, although the principle of the method was a better one.

The work described above has been done by the Board of Water Supply of the City of New York, John A. Bensel, President; Charles N. Chadwick and Charles N. Shaw, Commissioners; J. Waldo Smith is the Chief Engineer and Robert Ridgway, Past-President of this Society, is Department Engineer of the Northern Aqueduct Department. The work has been done under the direct charge of William E. Swift, Division Engineer of the Hudson River Division. The authors have been directly connected with the work.

Other papers on this and related subjects have been given before this Society by Mr. Robert Ridgway, M. M. E. N. Y., in "Subsurface Investigations of Board of Water Supply," on March 25th, 1908, and by Mr. Thomas H. Wiggin, M. M. E. N. Y., Senior Designing Engineer of the Board of Water Supply, in "The Design of Pressure Tunnel for the Catskill Aqueduct," on October 27th, 1909.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—The care and thoroughness which have so conspicuously marked every detail of the project now being carried out by the Board of Water Supply seem to have been exceptionally well illustrated in the work which the authors have described. Probably none of us can appreciate the number of disappointments which have doubtless been experienced and the patience which has been exercised in conducting the preliminary investigations essential for obtaining sufficient knowledge of the material to be encountered to permit of beginning actual work with a certainty of successful achievement. It must be gratifying to all of us to learn that the rate of progress made in shaft sinking increased after the contract work had been abandoned and full control was assumed by the city employees, and this notwithstanding the handicap placed on the supervising engineers by reason of municipal red tape,—a result quite inconsistent with the views generally held as to the efficiency of work carried out wholly under municipal auspices.

We have with us to-night a number of members and guests who have been intimately and responsibly connected with the undertaking, and we shall certainly expect them to discuss the paper.

ROBERT RIDGWAY, M. M. E. N. Y.—The authors have covered the details of the exploration work at the Hudson River Crossing so thoroughly that I cannot add much in the line of what they have written to add to the value of their excellent paper. Mr. Dodge and Mr. Hoke have both been identified with the work almost from the start under the Division Engineer, Mr. William E. Swift, and no one should be better qualified than they to write on the subject.

This paper is a record of difficult work accomplished and under way, and I am glad it is to appear in the *Proceedings* of the Society because it will there be available for the use of engineers who in the future may be called upon to do work of the same general nature as that described, and to whom the information collected should prove to be of great value. It is unfortunately the rule rather than the exception to allow such data, collected at great cost, to become lost and forgotten after it has served its immediate purpose, instead of collating it in such shape as the authors have done in this case for the use of others.

The Hudson River Crossing has probably attracted more attention from the general public than any other single feature of construction of the Catskill project. There is something which appeals strongly to the imagination in the crossing of a great aqueduct deep below a river so well known as the Hudson, and the public is naturally curious to know how the feat is to be accom-

plished. Without any intention of belittling the problem in any way, I have always felt that the aqueduct pressure tunnel, 4.3 miles long, under the Rondout Valley, which is now far advanced toward completion, was a bolder proposition than the river crossing, largely on account of the complex geological conditions which obtain there. At the Storm King Crossing the geology is far more favorable for a rock tunnel, and were it not for the great depth of the ancient rock gorge under the river, which requires the sinking of shafts 1 100 ft. or so below datum, I am sure the matter would not have received the public attention that has been given it.

There seems to be an impression in some quarters that the engineers of the Board did not have, until recently, any clear idea of how the crossing was to be effected; that they tried one plan and, finding it impracticable, tried another, and a third, and so on, and it was only within a few months that they settled on anything definite. This is not so. When the matter was first taken up in a preliminary way the several methods of crossing the river were thoroughly discussed, and it was early decided that, with the geological conditions favorable, a deep rock tunnel would afford the most desirable means of bringing the water across. The finding of a location for such a tunnel was then taken up, and after carefully considering the advantages and disadvantages of all the available crossings, the present Storm King line was finally adopted over four years ago. Work has been in progress there since, locating the bottom of the rock gorge and studying the geological and other conditions which would affect the construction and the depth of the tunnel. There has been an orderly development of the whole scheme from the start to the finish, and at no time has there been any reasonable doubt in the minds of the engineers as to the feasibility and advisability of it. After deciding on the method and location of the crossing, practically the only general question to settle was the depth of the tunnel. With the completion of the inclined borings described in the paper we are now in a position to do that. The information obtained from them was of a very encouraging nature, and has confirmed the predictions of the engineers and geologists as to the good tunneling conditions existing under the river.

I would like to make it clear that the inclined borings mentioned, which have given us such positive information, were a part of the original scheme of exploration, and not an afterthought as some persons seem to have inferred. In the first contract made for the core borings in and near the river, which was awarded on February 7th, 1906, provision was made for two such borings to be drilled from the surface of the ground on each shore and extended through the underlying rock to the middle of the river. The plan

was first to ascertain the approximate rock profile across the river by means of vertical borings, and from the profile fix the angles on which the inclined holes should be drilled. The primary purpose of the latter holes was to search out the position and extent of any zones or seams of distintegrated rock which might exist under the river in the material to be traversed by the tunnel. It was realized that vertical holes might easily miss a decayed zone in the rock and without the inclined holes its existence would not be discovered until encountered in the tunnel heading, with results that might be disastrous. The experience in the Croton Aqueduct tunnel under the Harlem River suggested this precaution. There the rock profile on the crossing line was determined only by vertical borings. It was first tentatively planned to cross 150 ft. below tide, and the tunnel from Shaft 25 on the Manhattan side was excavated at that grade a distance of 300 ft. or so to the contact between the gneiss rock and the limestone. There a waterbearing seam of distintegrated rock was found which caused a stoppage of the work. After locating its extent by diamond drill holes drilled at various angles by a machine set up in the heading, the shafts were sunk an additional 150 ft. or more, and the tunnel successfully driven from them under the river at a depth of over 300 ft. below tide.

The first vertical core borings made in the river at Storm King indicated such a steep pitch of the rock from the shores that it was impracticable to drill the inclined holes through it to the middle of the river by starting them at the surface of the ground. Their pitch would necessarily have been so great that they would only cross at a prohibitive depth. It was therefore necessary to defer starting these holes until the test shafts had reached a sufficient depth for the purpose.

As the authors have pointed out, the successful completion of these long drill holes reflects much credit on the contractors, Messrs. Sprague & Henwood, of Scranton, Pa. As far as I know, inclined holes of such lengths are unprecedented in this part of the country, and the magnitude of the task is apparent when one realizes the discouragements and difficulties that are attendant on ordinary diamond drilling, even under favorable conditions.

The authors, of course, did not go into the details of the design for the proposed pressure tunnel under the river, as it is beyond the scope of their paper. That subject was fully covered in Mr. Thomas H. Wiggin's able paper on "The Design of the Pressure Tunnels of the Catskill Aqueduct," presented to the Society October 27th, 1909.

CHARLES P. BERKEY.*—Everybody who is interested in these general matters and who cares to master the geological principles involved may understand why certain things have been done. One

* Professor of Geology, Columbia University.

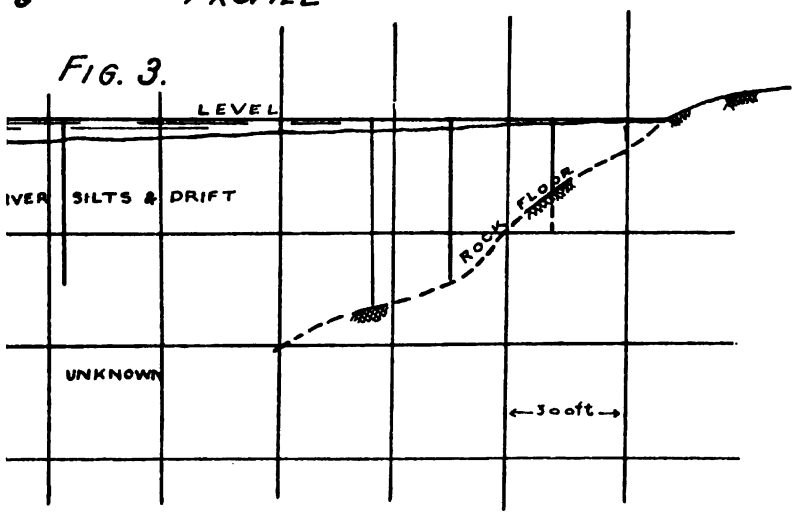
question I can make clear in a few minutes, that is whether or not the Hudson is very deep; how deep it is; whether, gradually like most rivers, it becomes deeper towards the sea, or whether there is a deeper place in some other portion of the river. Whether, in other words, it is deeper at Storm King than at New York City, and if so, how much?

At New Hamburg, or a little way above at Peggs Point, enough borings were put in the river to prove the condition represented in Plate 53, Fig. 1. The two sides have been traced down to a depth of over 230 ft. But there is a middle space whose depth is unknown. If there is any spot deeper than 250 ft., it is within the space in the middle of the river, which is not more than about 1 000 ft. wide. At Thirty-second Street, New York City, the explorations of the Pennsylvania Tunnel Company show a somewhat similar condition. The river is wider and a little deeper (see Plate 53, Fig. 2) and has been explored on the two side slopes pretty well, but there is again a space of about 1 100 ft. in width near the middle that is unknown. If the rocks are normal and uniform from the sources of a river to its mouth, the river channel becomes wider and deeper toward the sea. In this case, so far as width is concerned, it is both wider and deeper at Thirty-second Street than it is at New Hamburg and is of normal behavior no matter what is in the unknown ground. But at Storm King, which lies between the two the profile is quite different, as may be seen from Plate 53, Fig. 3. The gorge at Storm King is in harder rock than anywhere else along the river. Therefore, if there were a narrow place it ought to be at that point. On the contrary, it is wider. No simple river erosion would make so much difference under such conditions. It is wider than it ought to be for the great depth that is represented. If there is any place as deep as 500 ft. at Peggs Point or Thirty-second Street, it cannot be more than 1 000 ft. wide. But we know that at Storm King it is 500 ft. deep for a width of 1 500 ft. This is abnormal. It must have been caused by erosion of some special sort. In the northern part of the United States there is one cause of abnormal behavior of some rivers and that is glacial ice. If at any place a stream of ice could be jammed in and forced through a notch or channel it might gouge out a greater space, wider and possibly deeper than it was before, and we would get an abnormal profile at that locality. Here on the east is the range of Breakneck Mountain, and on the west side is Storm King. Between them is the pass that we call the Storm King-Breakneck entrance to the Highlands. This lies in the same direction as the grooves and glacial scratches on the surface north of the Highlands in the vicinity of Cornwall. It is apparent that on

PLATE 53.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON
RIVER CROSSING OF CATSKILL
AQUEDUCT.
DISCUSSION BY
CHARLES P. BERKEY.

'6 PROFILE

FIG. 3.



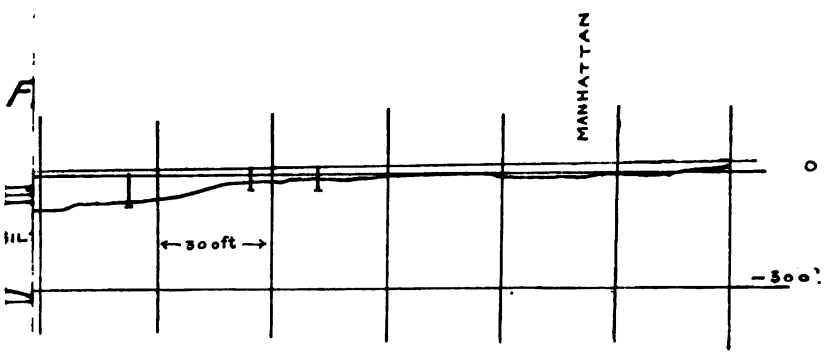
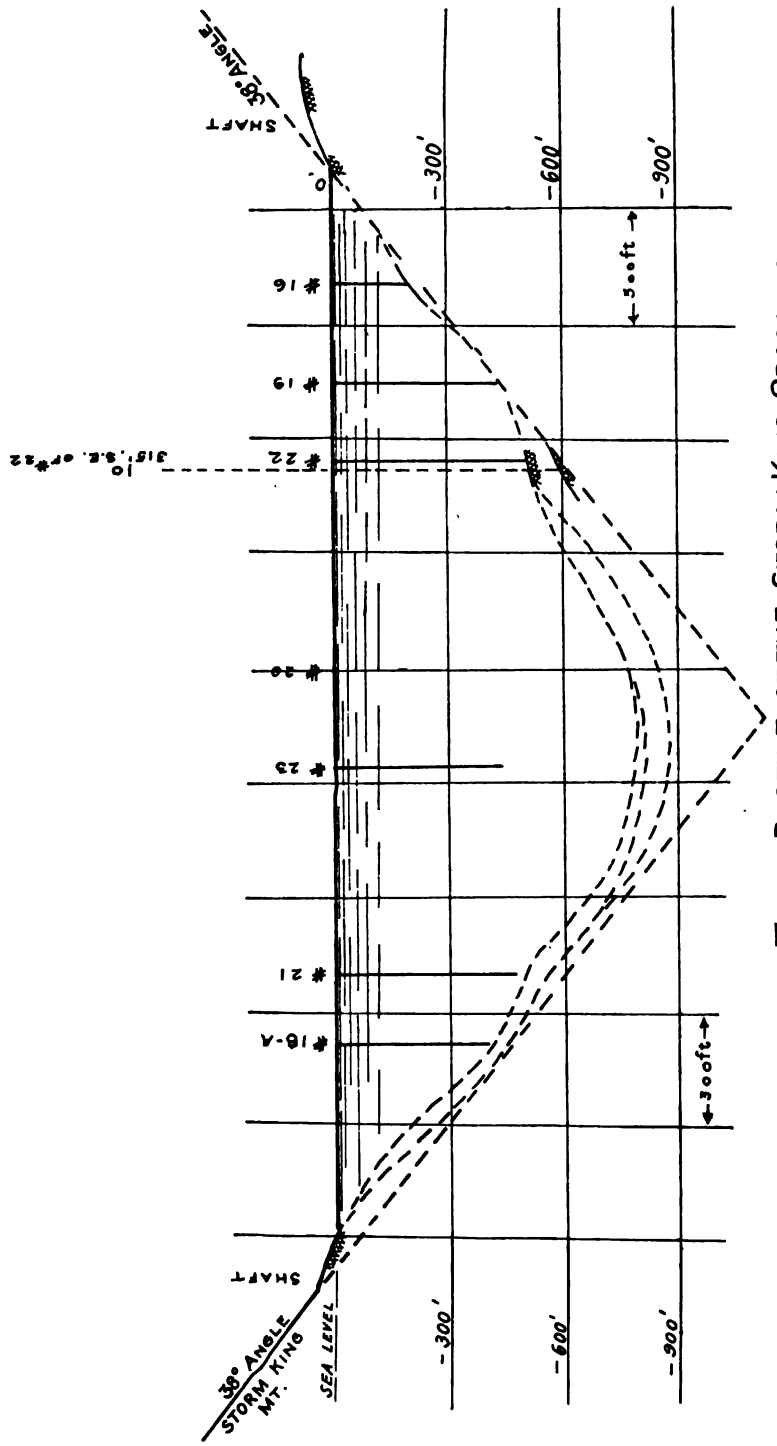


PLATE 54.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.
DODGE AND HOKE ON HUDSON RIVER CROSSING OF CATSKILL AQUEDUCT.
DISCUSSION BY CHARLES P. BERKEY.



TRIAL PROFILE OF THE STORM KING CROSSING
Based on Boring Data.

account of this sort of funnel-like special form of the north margin of the Highlands and on account of the direction of ice movement there would be a tendency to force an active ice tongue through the gorge at that point with an excellent opportunity for enlarging it. I believe that this is just what happened. The river gorge is wider than it ought to be and I am sure that the reason for it is ice erosion. One must at the same time admit that the ordinary V-shaped form characteristic of river erosion, has been destroyed and one cannot base an estimate of depth on this angle. There is only one thing that seems to furnish any suggestion of the depth of the Hudson River. The profile of the Hudson gorge, in the parts that are known, is not a simple V line. The profile is a succession of U's, the upper ones wider, the lower ones narrower, each one approximately 300 ft. deeper than the one preceding it and 1 000 ft. narrower (see Plate 54). Making an allowance for the total width of the river of about 3 000 ft., if this succession of steps holds good to the lowest one we ought to have a depth of 900 ft. It is absolutely useless to predict 900 ft., because nobody can tell whether each successive U is the same depth or not, but the best estimate anybody can make is 900 ft. or less and, therefore, in making the estimates some two years ago as to the possible or probable depth of the Hudson Gorge at Storm King, Professor Kemp and I both joined in the opinion that it would be found between 800 and 900 ft. It is also believed that at both New Hamburg and Thirty-second Street, there is an inner and very much deeper gorge not yet explored. I don't think that it is necessarily as deep as the river at Storm King, because I am sure that the river at Storm King has been gouged somewhat by ice and I am not sure that the river in other places has been modified in the same way.

The reasons for crossing at this place are very many. The condition of the rock is one of some importance. There is absolutely no other place on the Hudson within reach that has as good rock for this kind of enterprise as Storm King. The geologists all agreed on that conclusion almost from the beginning. The explorations already made have added much to the definiteness of these geological facts and have proven the correctness of the two most essential points—that the river gorge is not of prohibitive depth and that sound rock is continuous beneath the river.

WILLIAM F. JOHNES, M. M. E. N. Y.—I would like to ask one question. The author spoke of the driving of the casing as "light driving." I would like to know what he calls "light driving." About what was the weight of the hammer and what was the fall?

WILLIAM B. HOKE.—The hammer used weighed about a ton. It was raised about 6 in. and let fall on the casing.

GEORGE A. TABER, M. M. E. N. Y.—I think it would be interesting if the author would show a little more in detail how the hole was surveyed in a horizontal plane, and also if he would explain how the drill rod was forced upwards when they found it was going in an inclined downward direction.

MR. HOKE.—The horizontal survey was mentioned briefly in the paper. The survey was made in dip only, not in strike. We had no means of determining how the hole went horizontally.

The first hole was driven with a core barrel and shell and bit of the same size. They were $2\frac{11}{16}$ in. in diameter and the diamonds set with $\frac{1}{64}$ in. clearance. Rods of the same size were continued for about 60 ft. back of the core barrel, so that the hole would keep as nearly straight as possible. Then by removing these guide rods and attaching 2-in. rods directly to the core barrel it was thought that the effect of these smaller rods sagging downward would force the bits upward. Also, later, when drilling with the 2-in. rods, the core barrel and the bit were each a little larger than the rods themselves; that is, the rods were 2 in. in diameter and the bit was really about $2\frac{1}{16}$ in. in diameter and the core barrel about $2\frac{1}{32}$ in. in diameter. A special core barrel which was tapered down to the size of the rod was made and it was claimed that forcing the rods would drive the bit up. There was also another scheme which was not used. This was to drop a long steel wedge down the hole and turn the rods by that means.

ARTHUR S. TUTTLE, M. M. E. N. Y.—I would like to ask the authors if they will not give us more information relative to the difficulty experienced in keeping the casings from falling over.

S. D. DODGE.—The only instance where the casing fell over of its own accord was at Hole $\frac{18}{C\,1}$, where a single line of casing, 8 in. in diameter, was left standing without top support in about 80 ft. of water. There was a strong tidal current before which the casing bent until its top was perhaps 4 or 5 ft. out of plumb and the center of gravity of the unsupported part sufficiently far off its base to produce a bending moment too great to be resisted. If there had been other lines of casing inside the 8-in. they would probably have stiffened it enough to bear the strain. After this experience the casing was never left unsupported but was always held to the scow by a loop of wire cable until the outside casing was at its final depth, when anchor lines were fastened to it near its top. The later accidents were from collisions which either broke anchor lines or dragged the anchors.

THE HUDSON'S HIGHLAND GATEWAY.

Pause, stranger, for a moment, and look on this fair scene,
Two stately mountains tow'ring high; and peaceful in between—
The Queen of Rivers silent flowing ever on and on,
Till mingling with the greater sea, her goal is fairly won.

Yon massive pile of granite rock which Time could not decay,
Was guarding well this river-gate, ere man saw light of day;
And we, with borrowed forces, which God, Himself, commands,
Would mould it into usefulness to serve our own demands.

Already have the artisans begun on their attack
Nor will the din of hammers cease, nor zeal nor ardor slack,
Till all their labor finished, that day shall happen, when
Kind Nature's purest water greets four million thirsty men.

The above verses were written in October, 1907, by Mr. Eric T. King, Assistant Engineer, Board of Water Supply, when the work of sinking the shafts for the aqueduct crossing at this location had been recently commenced.—ED.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 59.

PRESENTED OCTOBER 26TH, 1910.

THE STREET PAVEMENT PROBLEM IN THE BOROUGH OF MANHATTAN.

BY GEORGE W. TILLSON,* M. M. E. N. Y.

WITH DISCUSSION BY
ARTHUR S. TUTTLE, NELSON P. LEWIS, A. PRESCOTT FOLWELL, HENRY W. VOGEL, EDWARD A. MILLER, WM. R. PATTERSON, WM. H. CONNELL, JOHN T. FETHERSTON, SAMUEL C. THOMPSON AND GEORGE W. TILLSON.

The pavement proposition in Manhattan presents a different phase from that in any other borough of the city. In fact, it is different from that in any other city of the country even. While the Borough of Manhattan is really only one part of a great city, as far as street administration is concerned it is practically a municipality in itself. It comprises in round numbers twenty-two square miles of territory, twenty of which have all its streets paved, and are well built-up. The Borough of Brooklyn with its 50% more miles of pavement than Manhattan is only about one-half paved, while the other boroughs have only begun the work of street pavements. It will be seen, then, that in Manhattan the main problem is to maintain the present pavements rather than to provide new ones. By the word "maintain" is not meant simply to make repairs, but to keep perpetually a good pavement on the streets.

The question naturally divides itself into two parts, viz.: the actual physical performance of the work and the raising of the funds to cover the cost of the same.

The first pavement in New York was laid of cobble-stones on Stone Street in 1656, and this material was considered standard

* Chief Engineer, Bureau of Highways.

for many years, and indeed was practically the only kind used until 1849 when "Russ" blocks were laid on Broadway as far north as Franklin Street. These blocks were made of stone from Staten Island some two or three feet square, grooved on the grades to give a foothold for horses.

The now obsolete Belgian blocks began to supersede cobble-stones in 1852, when they were laid on the Bowery. The present shaped granite blocks were first used about 1876, although some patented granite blocks of larger size had been laid a few years previously.

A small piece of asphalt was laid near the Battery in 1871, but it was not adopted as a standard material till about twenty-five years ago. Asphalt-blocks have been in use for twenty years and the present form of treated wood blocks six years, although an experimental wood pavement was laid on lower Broadway as far back as 1839. At the present time the standard materials for the Borough of Manhattan are stone, asphalt (sheet and block) and wood.

Although the general materials have been decided upon, the question of selection of which kind for any particular street is by no means a simple one. On the contrary, it is quite complex. Streets are built to serve the general public as a whole, and in particular the different people doing business upon them. These interests often conflict, and perhaps as often the interests of each class conflict. To harmonize these interests is always difficult and sometimes impossible. Certain principles, however, governing the selection of materials, can be established which will materially aid the city official who has to decide these questions.

The general properties that are commonly required of a pavement are that it shall be durable, smooth but not slippery, free from noise under traffic, and sanitary. These properties may seem simple, but it is safe to say that, while they are all contained in the materials mentioned above, no one pavement has ever been constructed that contained them all. It is the harmonizing and modifying of these different traits to suit the needs of the different streets that will test the knowledge and skill of the engineer.

For heavy traffic streets where the pavement is in constant use under all weather conditions and where the question of noise is not important, a well-laid granite pavement will be most satisfactory; but suppose, for instance, that such a street passes a hospital and

it is necessary to reduce the noise to a minimum, then a change must be made. Under such conditions, where the grade is less than 2%, the author would always recommend wood block. On steeper grades asphalt, sheet or block, to about 5%, when a return must be made to granite. The problem then is to use this material in such a way that it will produce the least possible noise under traffic. It is a well-known fact that American stone pavements are inferior to European more on account of the character and shape of the blocks themselves than the material. If, then, the blocks are so dressed that when laid the surface of the pavement shall be smooth and the joints between the blocks so small that it is practicable to fill them with a bituminous compound, the noise element will be eliminated to as great an extent as possible.

If, on the contrary, the traffic on a street be heavy, the question of noise on its entire length all-important and the grades below 2%, the material to be used is undoubtedly wood block.

On light traffic, business or residential streets, either asphalt or wood can be used according to local wishes within grade limitations. It must be remembered, however, that on streets not in continuous use grade restrictions need not be so strictly adhered to, as on the comparatively few days when smooth pavements are unduly slippery they can be avoided to a great extent. To sum up briefly, then, the principles governing the selection of materials for different streets, one would say, first, for heavy traffic wholesale streets, granite block; second, for heavy traffic streets where noise must be eliminated where possible, wood block, asphalt-block, or improved granite, according to grades; third, for light traffic or residential streets, asphalt or wood, according to local desires.

The above conclusions have been reached by taking into account the effect of using materials that do not contain all the requisites previously stated so as to produce the best results. For instance, granite is durable, fairly smooth when well laid, but so noisy as to prohibit its use on certain streets. Wood block is smooth, durable and almost noiseless, but slippery under certain conditions. Asphalt is smooth, less slippery than wood block and also less durable than either wood block or granite. With well-laid granite there is not much difference in the sanitariness of either of the above kinds.

It has been considered that a smooth pavement should always be laid whenever conditions are such as to permit it.

It will be noticed that up to the present time no mention has been made of the cost of the different kinds of pavement. The reason for this is that the author believes that in the Borough of Manhattan the pavement best adapted to any one street should be used irrespective of its cost.

In deciding specifically upon the material for any particular street the question of cost sometimes comes up and may be an important factor in reaching a decision; then the first cost and frequently that of repairs must be taken into consideration. Interruptions to traffic are very objectionable and should be reduced to a minimum. Streets are in use at all times and under all weather conditions. If a pavement be put in good condition and then weather conditions arise so that it is not possible to make repairs for three months, for instance, and in the meantime it becomes bad and in a general state of disrepair, it can safely be admitted that it has not been constructed of proper material. This last principle is important in making the decision. From all reports it is probable that the pavements of the cities of London and Liverpool are kept in better condition than those of any other large city. It would be of the greatest importance to know whether this is due to a more intelligent selection of material, better construction, or a more uniform and systematic method of making repairs. It is very likely due to all three, and a study of this would undoubtedly be of great value to American cities.

On January 1st, 1910, there were 440 miles of paved and 30 miles of unpaved streets in the Borough of Manhattan, the pavement being divided approximately as follows:

Sheet Asphalt	260	miles
Block Asphalt	45	"
Wood	12	"
Macadam	5	"
Stone	118	"
	440	"

If to this amount there be added 30 miles now unpaved and 34 miles for new streets, it will be seen that 504 miles of pavement must be cared for when the borough is entirely developed. How much of this must be laid annually depends upon how long any particular kind of pavement will last. This depends so much upon special

conditions that in this connection it has not been deemed advisable to go too deeply into the niceties of the subject, but after careful consideration to assume arbitrarily eighteen years as the average life of all pavements. This would mean that each year the borough must relay twenty-eight miles of pavement in order to keep the streets in good condition. Last year Manhattan laid between twenty-seven and twenty-eight miles.

Different kinds of pavements cost different amounts, but as all the pavements are at present existing under so many varying conditions as to foundation, etc., one price of $2.75 per sq. yd. will be adopted for all materials, including curb and foundation. Figuring 20 000 sq. yd. to the mile outside of railroad area, the borough must lay annually 560 000 sq. yd., which, at $2.75 per yd., will amount to $1 540 000 for the annual expenditure for new pavements.

If the system of guarantees in vogue now is kept up, namely, five years maintenance for asphalt and wood, and one year for granite, assuming the proportion of stone to be about as at present, there would remain to be cared for annually by the borough 7 420 000 sq. yd.

Just how much money will be required for this work is uncertain. The asphalt repairs in the Borough of Manhattan on streets out of guarantee cost in 1906, 34 cents; in 1907, 20 cents; in 1908, $17\frac{7}{10}$ cents; and in 1909, $11\frac{7}{10}$ cents. At present it looks as if the cost for 1910 would be somewhat lower than 1909. The records of cost of repairs to stone pavements have been so kept, that no definite figures can be given. But if a general sum of 14 cents per sq. yd. be taken as the annual cost of all pavements out of guarantee, it is thought that it will be approximately correct. This would make the annual expenditure for repairs $1 038 800.

The money necessary for paving, repaving and keeping in repair the streets of Manhattan is obtained in three ways: by special assessments for all original pavements, by the issue of corporate stock for repaving a street where the original pavement was paid for by special assessment, and by a budget appropriation for general repairs to all pavements out of guarantee.

There seems to be little question that the proper method of paying for a first pavement is by special assessment, but in the judgment of the author the propriety of paying for all repaving out of

corporate stock issues is at least debatable. The proceeds of corporate stock are supposed to pay for permanent improvements, the theory being that the present generation should not pay entirely for an improvement that is to be enjoyed by a future generation. This is undoubtedly correct, but how an improvement like a street pavement with a life of eighteen years can be considered permanent, is difficult to understand. Corporate stock for repaving purposes is issued for a term of 50 years. When any issue of this kind is redeemed, the pavements laid under it have been renewed twice, requiring two additional issues of stock, so that after all of the borough streets come under this system the City will be paying interest on three sets of bonds issued for the same purpose, and also providing for a sinking fund to redeem them.

In the 504 miles of streets in the borough, at 20 000 yd. per mile, there would be a total of 10 080 000 sq. yd., which, at $2.75 per yd., would cost $27 720 000 for one pavement. The interest on this amount at 4% is $1 108 800. This is, however, on one issue only; for the three issues previously referred to it would be three times as much or $3 326 400. As three pavements will last, however, fifty-four instead of 50 years, the life of the bonds, this amount will be reduced to $3 080 000 as the annual interest charge for pavements, if the present financial scheme is kept up. To this must be added the amount necessary to be deposited each year to provide a sinking fund to pay off the bonds on maturity. This, figuring on 4% interest, would amount to $512 642, or an annual budget charge of $3 592 642 for providing funds for relaying pavements. To this must be added the annual repair cost of $1 038 800, making the total annual expenditure for pavements $4 631 442. This also means a perpetual issue of corporate stock of $77 000 000. In these days of "What is the debt limit?" and the introduction of bills in the legislature providing means of increasing the indebtedness, are not the above figures for the one and comparatively small item of street pavements rather appalling? Is not the real solution of the financial problem to do away with the necessity of borrowing rather than increasing the City's credit by legislation? To an engineer and not a financier it would seem so. There are two methods of doing this: one by providing for all repaving in the annual budget, and the other by paying for it by special assessment.

Budget Appropriation.

It has already been shown that under the assumption of this paper that an expenditure of $1 540 000 must be made annually for new pavements after all the streets have once been paved. To this must be added the cost of repairing the pavements out of guarantee to find the total necessary budget appropriation. This repair cost has been found to be $1 038 800, which, added to the above $1 540 000 makes a total of $2 578 800 as the total budgetary requirement for maintaining pavements in the Borough of Manhattan if the total cost is included in the budget. The word "maintaining" is used here in its broadest sense and means the annual repair of all pavements and their renewal when necessary. Should this method of providing funds prevail, the money collected should be placed in a separate fund to be a continuous one and known as the "Street Maintaining Fund," so that the money saved in one year could be used in another, as the above figures are based on averages, so that even if correct they would not be wholly applicable for each year.

From the above figures it will be seen that under the direct tax method the amount to be levied for the entire work will be much less than the interest charge only, and $2 052 642 less when the interest, sinking fund and repair charges are included.

Annual interest charge	$3 080 000
Annual repair charge	1 038 800
Annual sinking fund charge	512 642
Total corporate stock scheme	$4 631 442
Total budget scheme charge	2 578 800
Annual saving, budgetary scheme	$2 052 642

Does it not then seem to be a business proposition from a financial standpoint? Then, again, is it not a business proposition for any corporation to pay its running expenses out of its income and not by increasing its indebtedness? Should any private corporation adopt such a method it would be a question of time only when it would become bankrupt. Can any one deny that the keeping of its streets in good condition is anything other than a running expense? It would seem that there could be but one answer.

Special Assessment.

There are some people who contend that all pavements, both original and renewals, should be paid for by a direct assessment upon the abutting property. This is a much-mooted question and will admit of more discussion than can be given here. To treat the matter logically and scientifically it would seem that possibly some streets might be paid for wholly by assessment and on others only partially. For instance, such streets as Broadway, Fifth Avenue, or any of the thoroughfare streets are used more for the general public than by the tenants or owners of abutting property. In such cases it would not be illogical for the City, as a whole, to stand a portion of the cost of the repaving, even if the general scheme of special assessments were adopted. On the other hand, practically all the cross streets north of Fifty-ninth Street are used locally only, for the use of the property-owners, and the general public has very little interest in their condition; so that in such cases a special assessment would not seem a hardship. But if this differentiation should be attempted, there would be many streets on the border-line where the determination of how the payment should be made would be difficult, and much contention and dissatisfaction would unavoidably arise.

To the author it seems that the budget method is undoubtedly the best of the three and the one that the City is bound to come to before many years.

In this financial discussion of the problem the author does not pretend to claim that his figures are absolutely correct, but approximately so, and certainly of sufficient accuracy to make his conclusions reliable, as the principles applied are correct, and any adjustments necessary would be relative only and not affect general results.

After the financial conditions have been satisfied the engineer has to perform the work necessary to keep the streets in good repair physically.

The damage to pavements is the actual wear and tear of street traffic and by extraneous causes. The first is provided for by repaving certain streets and repairing others. The selection of the streets to be repaved and the material to be used is a work requiring great care, judgment, and a complete knowledge of the require-

ments of each street. In order to do this intelligently and systematically a traffic census should be taken of all the business streets so that the engineer would have positive and specific instead of general knowledge of the existing conditions. Many claims are made of the needs of certain streets by interested parties which are entirely without foundation, and the engineer often requires positive facts to refute them. If the financial scheme outlined in this paper be adopted, it will be known in advance how much money will be available, and the official in charge can determine intelligently how to conduct his work. He will know that if he saves money in repairs this year he will have more for repaving next year. He can plan two or three years in advance what streets are to be repaved each year and so know upon which particular one he should make permanent and on which temporary repairs.

It is not always easy to determine what streets should be repaved and which repaired, and the question of funds often determines the decision; but if both classes of work are payable out of the same fund this trouble is eliminated. During the winters of 1908 and 1909 a complete survey was made of all the stone streets in the Borough of Manhattan and recorded on a map made showing in different colors which portions were in good condition and which needed repairs, and which should be repaved according to the judgment of the engineers who made the survey. This result could be reached by examination. By an inspection of this map a very fair idea of the stone pavement requirements for the next three or four years could be obtained.

With the asphalt pavements, however, the question is not quite so simple, and this must be studied in a different way. An asphalt pavement in bad condition is generally full of holes with the asphalt worn down to the foundation. By patching the holes it can be put in good repair till after a certain time more holes occur and they must again be patched up. The frequency of this work and the cost of same will determine when the pavement should be entirely relaid. The entire expense of maintaining a pavement, no matter how its initial cost has been met, consists of this initial cost, the interest on same, the cost of repairs, and the establishment of a sinking fund that will be sufficient to replace it when it becomes worn out.

Putting this into the shape of a formula it will be

$$A + C\,I + \frac{R}{N} = \text{annual expense},$$

when N = life of pavement,
C = cost per square yard,
I = rate of interest,
R = total cost of repairs,
A = sinking fund to be paid each year to equal C at end of N years.

It follows then that an exact account should be kept of the cost of repairing each street each year, as it often happens that a large amount of repairs made one year on some streets will materially reduce the cost in succeeding years; while on others the same amount of work must be done until they are repaved. In other words, the entire history of each street should be accurately kept. Applying the figures previously decided upon to this formula, the annual expense of maintaining an asphalt pavement is twenty-five cents. Consequently when the annual cost of repairs on any particular street reaches this amount the question of its repaving should be carefully considered. This is an average result, but knowing the age of a particular pavement and its repair cost, by the application of the formula it can be determined positively whether, from a financial standpoint, it should be repaved or not. This would seem to demonstrate that not only can it be accurately and scientifically determined when an asphalt pavement should be relaid, but also that it is difficult to determine in any other way. Where a city charter requires that repaving shall be paid by special assessment and repairs out of the budget account, this determination is important.

By damage to pavements by extraneous causes is meant the damage caused by openings made in the pavements by plumbers, corporations and builders. Just what this amounts to no one can tell positively, but after careful consideration the author believes that if a pavement were undisturbed it would last 25% longer than it does with the treatment it receives in the average American city. In the year 1907, in the Borough of Manhattan, the length of trenches more than 100 ft. long opened for all purposes was 129 miles. This was in 437 miles of paved streets. In 1908 and 1909

the amount was less, owing undoubtedly to the financial depression of 1907. But the prospects for 1910 with a better business and the activity of the Department of Water Supply are that it will be a banner year.

It is often said that permits should not be given for opening a new pavement for any purpose. They should not, but they often must be. Subsurface work is never perfect, and the street must be opened to make repairs. Conditions change, a twenty-story building has been torn down this season to be replaced by one of thirty-two. The new building will require additional subsurface facilities, and an investment of millions must not be held back on account of damage to a mere pavement. While the Borough of Manhattan is changing as it is to-day, it seems to be impossible to prevent a large number of street openings. The problem is to reduce the number to a minimum.

If the official in charge of the streets could know several years in advance how much money would be available for street work and also had a thorough knowledge of the condition of each street, he would be able to tell one year what streets would be repaved the next. The property-owners on the streets affected, the different corporations working underground, as well as all interested city departments should be notified of this determination and that all repairs or new extensions must be made during the current year. If a determination were so made it would be possible for the Bureau of Highways to prepare all plans and make all contracts for new pavements in the winter. The contractors would know in advance what work each would have and could provide for materials more advantageously and in such a way that deliveries of materials could be made more promptly and expeditiously. Where a large amount of work is to be done and a regular system carried out this would be important.

By the adoption of such a plan openings in streets would be reduced to a minimum. They would not be prevented. That could never be done with our present system of using our underground street areas, and probably never will until Manhattan ceases to grow and becomes peaceful and quiet like a country village.

In maintaining the asphalt pavements under guarantee a very vexatious situation arose about three years ago. To those acquainted

with the history of the asphalt industry it will be known that there was a coalition of the several asphalt construction companies in the early part of the last decade. This meant that many of them went out of business, some of whom held long-time guarantee contracts in Manhattan. Repairs were made on these contracts for some years by other companies, but in the latter part of 1907 this practice was discontinued, making it necessary to have the pavements repaired under the maintenance clause of the contracts. This involved a great amount of study as to the proper method of procedure in order to produce practical results and still maintain the City's legal rights. On some of the contracts there was considerable money held for this contingency, but on others only a bond. While the money held out the streets were repaired and the cost charged to the retained percentage, but when it was exhausted special funds had to be provided by the Board of Aldermen and Board of Estimate. This was also the procedure where no money had been retained. In many cases much delay ensued and streets were in bad condition when the Bureau of Highways was utterly helpless.

Just what this meant can be inferred when it is known that at one time for the above and other reasons the maintenance on more than 450 000 yd. of asphalt pavement had been abandoned by the original contractors. At the present time the guarantee period on some of these contracts has expired; others soon will expire; and some of the worst streets have been entirely repaved so that the work is much simplified.

Assuming, now, that the money has been provided as herein indicated, it should be so appropriated as to be under the complete control of the Borough President. This is absolutely necessary. In past years the street repair fund for Brooklyn was called "Labor, Maintenance and Supplies," and for Manhattan in 1909 "Maintenance of Highways." Any work that pertained to repairs could be charged to these funds. These titles evidently seemed to the budget-makers to cover a multitude of sins, but they didn't. They only permitted the officials to use the money to the best advantage.

To correct the supposed abuses the segregated budget was evolved, and as a result the Manhattan Highways budget for 1910 is made up of twenty line-numbers not including administration or

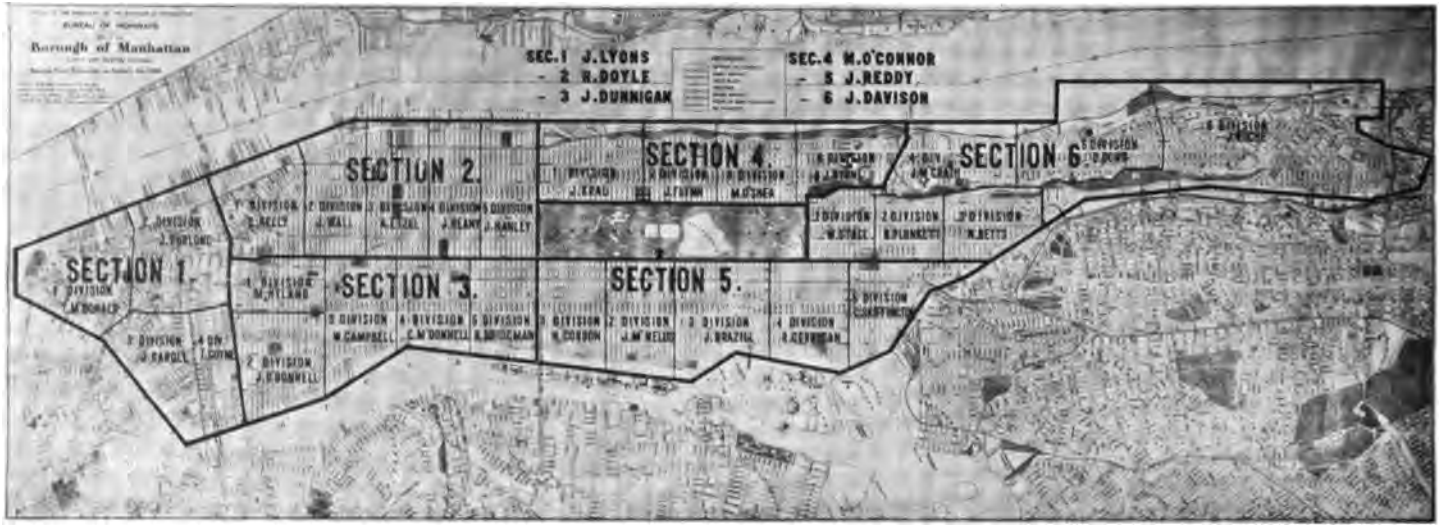
engineering. One of these line-numbers is made up of eleven and another of thirteen items in the supporting schedule. The result is that no money can be used for any work other than as stated in the line-number without the consent of the Board of Estimate and Apportionment and the supporting schedule of each modified to suit the change. This involves delay, extra labor in the executive offices as well as for the bookkeepers of the Borough President and the Finance Department. It also encumbers the records of the Board of Estimate and Apportionment. The whole aim of the Bureau of Highways is action. That is the only thing that justifies its existence; its watchword should be action, and any legislation pertaining to this bureau should accelerate and not retard this action.

It will be said by the exponents of the segregated budget that it is necessary to protect the City from dishonest and ignorant officials. There have been dishonest and ignorant officials since officials existed, and there will be for all time to come unless human nature changes, but they can be easily watched and taken care of. A small central bureau made up of, or advised by, men who have had experience in construction could without any difficulty advise the Board of Estimate and Apportionment whether or not any Borough President was misappropriating his funds. It is true, in the judgment of the author, that more loss is incurred by the reduction of efficiency to the honest officials than by the waste of the dishonest or ignorant ones by too restrictive rules and regulations. Let, then, the official have a free hand with his appropriation but be held to a strict account for its expenditure.

In carrying out the work of street maintenance in Manhattan it is divided into three parts, namely: construction, repairs to unpaved streets and stone pavements, and repairs to asphalt pavements, each under the charge of an assistant engineer.

Construction.

This work is all done by contract. The engineer in charge has a force of inspectors under him sufficient to place one or more, as the case may require, on each street as it is being improved to see that the contract requirements are being fulfilled. He also has two assistant engineers, one of whom or himself, visits each street every day to see that the inspectors are doing their duty, to give any



MAP OF THE BOROUGH OF MANHATTAN, SHOWING REPAIR GANG SECTIONS OF THE BUREAU OF HIGHWAYS.

PLATE 55.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.
TILLSON ON THE STREET PAVEMENT PROBLEM IN BOROUGH OF MANHATTAN.

special directions that may be required, and to take general charge of the entire job.

Asphalt Repairs.

This work consists of keeping in repair all of the asphalt paved streets, sheet and block, both under and out of guarantee, a total, as has been previously stated, of 305 miles.

The out-of-guarantee, or maintenance streets, as they are called, are repaired by contract and paid for per square yard of pavement laid.

In order to facilitate the entire work the borough is divided into six inspection districts as follows (see Plate 55): Section No. 1, that part of the borough south of Houston Street; Section No. 2, that part between Houston and Fifty-ninth Streets, Fifth Avenue and the Hudson River; Section No. 3, that part between Houston and Fifty-ninth Streets, Fifth Avenue and the East River; Section No. 4, that part between Fifty-ninth Street, Manhattan Street, Central Park West and the Hudson River; Section No. 5, that part north of Fifty-ninth Street and east of Fifth Avenue; Section No. 6, the remainder of the borough. These sections are divided into divisions, generally six, each division being in charge of an inspector and each section being in charge of a chief inspector. The division inspectors report to the chief inspector, who in turn reports to the assistant engineer in charge.

The division inspectors patrol their divisions daily, making notes of all defects in the pavement from whatever cause, whether by wear and tear, fire, plumbers, corporations, water department or builders. These are all located and recorded on a prepared blank which is forwarded to the main office. The clerk in charge of this branch sends to each contractor a copy of the list when the same refers to a guaranteed pavement. The maintenance streets are looked after directly by the engineer in charge.

In addition to the above on Friday of each week the chief inspectors report to the engineer all streets in their respective districts that are in disrepair. These lists are also sent to the contractors and each one is expected to repair all the streets on his list before the end of that week. This plan has been in effect for about three years and has produced admirable results. The author

believes it is impossible to keep the streets in good condition without a competent and systematic inspection.

In compiling statistics of the repairs to asphalt pavements in different cities the unit has generally been the cost per square yard. This, while somewhat satisfactory is not entirely so, as the cost of doing the same work varies considerably. If, however, the percentage of the maintained pavement actually removed be given an exact comparison can be made. The following figures have been made up by both plans and relate to the repairs of sheet asphalt pavements out of guarantee in the Borough of Manhattan during the last five years, the figures for 1910 being estimated:

	Percentage of pavement removed.	Cost per square yard, in cents.
1906	23	34
1907	18	20
1908	15	17.7
1909	12	11.7
1910	13	11.3

It would seem from the above figures that the limit of the reduction had about been reached.

Stone Pavement Repairs.

Since the first of the year this branch has been put under the jurisdiction of the Chief Engineer, and directly in charge of an assistant engineer. The borough is divided for convenience into sections with practically the same boundaries as for asphalt repairs, except that Section No. 1 is divided into two, and the lower half of Section 4 added to Section 2 and the upper half to Section 6. In the several sections are five or six repair gangs, made up as follows: 1 foreman, 2 pavers, 1 rammer, 6 laborers, and 2 horses and carts. All of the gangs in a section are under the supervision of a general foreman who reports to the assistant engineer. The engineer knows the requirements of each section and tells the general foreman where each gang should be located. Each gang is supposed to do a definite amount of work each day, to be varied, of course, according to special conditions. The foremen and general foremen are held responsible for their own gangs.

It seems impossible to obtain reliable figures as to the cost of keeping stone streets in repair. The amount of money spent in the different cities for such purpose can be learned, but that is a different proposition, as probably no American city spends enough to keep its streets in good condition. In speaking of this an official of a neighboring city said to the author: "We spend all the money we can get, but it is not enough for our purpose." It will be seen, then, of what little value such information is.

It is expected that at the end of three years with the present appropriation, there will not be a bad street in the Borough of Manhattan, except where the conditions are beyond the control of the Bureau of Highways.

The northern part of the borough where are all the macadam and unpaved streets forms another section. This can be taken care of by three gangs under the control of a general inspector, who reports to the same assistant engineer. As the streets become paved and the macadam changed to a permanent pavement, this section will be absorbed into the general repair system.

In summing up, then, the conclusions of this paper it should be said:

1. That a sufficient sum of money should be appropriated by January 1st of each year for all maintenance work of that year.

2. That the money so appropriated should be placed at the disposal of the Borough President, he to be held responsible for results.

3. A sufficient knowledge should be had by the executive officials of the characteristics of all paving materials in use.

4. That a complete knowledge should be had by the executive officials of all the pavements in the borough, together with the special requirements of each street.

5. That the maintenance fund should be expended by repairing or repaving the streets, determining the method and material according to the knowledge specified in paragraphs 3 and 4.

The author firmly believes that, if the above requirements were complied with, in a few years the pavements of Manhattan would be put, and could be kept in practically a perfect condition, and that it is the most feasible way to accomplish it.

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—This paper deals not only with the construction and maintenance of pavements, but also clearly brings out the importance of properly financing the work. A very large proportion of our members are more or less intimate with some features of this subject, and I have no doubt that many of those present are prepared to offer a discussion concerning the various points which have been raised.

NELSON P. LEWIS, M. M. E. N. Y.—We must admit that the engineer is rather prone to confine himself to the technical work of construction or maintenance which may be imposed upon him, and that he is usually reluctant to offer any suggestions relating to the financial side of the problems. I am exceedingly glad that the author of this paper has had the courage to present with such prominence as he has done, the financial features of the paving problem of this City. Is it not the engineer's duty to carefully study this phase of the question and not only think about it, but also express his views and emphasize them, if necessary? Mr. Tillson has shown very clearly to-night, in figures that can scarcely be challenged, the folly of the present system of issuing 50-year bonds to pay for pavements which will last, in some cases, 5 or 6 years, in some cases perhaps 25 years, or, we will say an average of 18 years which Mr. Tillson has adopted.

In order to avoid this ruinous policy it would seem to be necessary to adopt one of two alternatives, first, a return to the old-fashioned method of assessing either in whole or in part the cost of repaving upon the abutting property. Such a change in policy would undoubtedly be strongly opposed, especially by those who have not yet been furnished with a modern pavement at the expense of the City at large. Before consolidation the City of Brooklyn assessed one-half the cost of repaving, while the other half was borne by the City, and this has always seemed to me a fair and logical plan which permitted those who were willing to contribute toward the expense to have the preference. It is frequently stated that on important thoroughfares, where the life of the pavement is shortest, the general public has so great an interest and uses the street to such an extent that it is unfair to place the burden of pavement renewals upon the abutting property, and yet it is the property fronting upon those streets which is the most valuable and best able to bear such a burden. There is another side, however, to the question, and that is that the value of the property on such streets is reflected in the records of the Tax Department, and the much higher taxes which this property pays may be thought to entitle it

to the maintenance and renewal of the street pavement without special assessment.

The second alternative is to provide for such renewals of pavement as may be necessary each year in the annual budget. Of course, we all realize the natural desire to keep down the tax rate, and yet the annual cost of the City's debt service is increasing at such a stupendous rate that sooner or later we will be obliged to face the situation and pay cash, instead of borrowing, and thereby effect an ultimate saving.

Mr. Tillson has spoken of London as having, perhaps, the best maintained streets of any great city in the world. This statement may be justified when we consider the great variety of pavements in London, but in my judgment there are at least two cities more conspicuous for the admirable condition of their pavements than is the City of London. One of these is Liverpool, which is distinctively a stone-paved city. The perfection of the surface of these stone pavements is remarkable, and is probably due to the fact that they use paving stones of small size, cut with great accuracy and laid with special care; but of equal, if not greater, importance is the fact that when these pavements are laid they are only permitted to be opened when there is an absolute necessity for it. The other city which was referred to is Berlin. This is distinctively an asphalt-paved city, and in perfection of surface, in absence of any sign of mutilation, and in absolute cleanliness, the streets of Berlin are in a class by themselves.

In both of these cities the problem is doubtless simplified by reason of the fact that practically all of the public utilities, except, perhaps, the gas service in Liverpool, are owned and operated by the cities, these including even the traction lines.

There is apparently a cordial co-operation between the different branches of the city government in minimizing the expense, inconvenience and discomfort due to pavement openings. The lack of such co-operation is most conspicuous in the City of New York, not only between the City and the public service corporations which have structures in the streets, but also between the different branches of the City Government. It does not seem reasonable that one city department should claim and exercise the right to open at will pavements which are under the control of a co-ordinate branch of the Municipal Government, and yet I understand this right is claimed and exercised without even consulting the department which has control and responsibility for pavements. A large steel water-main is now being laid in the Borough of Brooklyn. For a portion of the distance it is located in a street on which an asphalt pavement has recently been laid. This new pavement extends for several blocks along a public park,—not an ordinary park with trees and

shrubs and walks, but a great playground, or level open space, extending for approximately a half mile. It would have been very simple to deflect this watermain outside the lines of the street and carry it through this playground, where it would not have interfered with any pavement, and where in all the years to come access could be had to it without pavement mutilation. Upon inquiry of the officer in charge of pavements as to why such a course had not been pursued, he replied that he did not know that this main was to be laid until he saw the street torn up. Such conditions could not exist in any city which is conspicuous for good pavements.

It is very impressive to be told by the City Engineer of an English city that a certain street was paved twenty-five years ago, and that during a quarter century of constant use not a single paving stone has been removed and not one penny has been spent for repairs. It happens that in the street referred to a pipe subway was constructed just before the pavement was laid, but that does not of itself explain the absence of all signs of mutilation and disturbance which is a conspicuous feature of the streets in a number of foreign cities. In Berlin, to which reference has already been made, there are no such things as pipe subways, so that the secret of the admirable condition of Berlin's streets appears to be intelligent co-operation between the different branches of the city government and efficiency of administration. Ultimately such conditions will prevail in New York City, and it is only fair to the author of the paper under discussion to say that since he has been in charge of the highways of the Borough of Manhattan and has introduced the system of inspection and records which he has outlined in his paper, a marked improvement has taken place in the condition of the streets of this borough.

A. PRESCOTT FOLWELL.*—Mr. President, I am not a paving expert like the gentleman who read the paper, but I have in the past obtained some ideas from him from which some new ones may possibly have sprouted.

At one time, two or three years ago, while riding over some streets of a city (I do not recall the exact city) Mr. Tillson called my attention to a certain street and said, "We have had our attention called to the perfection of the pavement on this street, and the gentleman stated incidentally that he had been in New York and had seen New York pavements, and did not think it was necessary to say any more." (That was in 1907.) Mr. Tillson continued, "Look down that street and see how many teams you see, then cast your memory back to New York streets and recall how many teams you saw there." The comparison as to traffic between this street and the New York streets was certainly in favor of the latter, ex-

* Editor, *The Municipal Journal and Engineer.*

plaining their more rapid wear and the greater difficulty of keeping them in repair.

I wish to say something about traffic censuses. It is possible that there would be no immediate financial results from taking such a census; but the knowledge obtained of the traffic on these streets as compared with the cost of maintenance of the various classes of pavement would, in the end, add greatly, in my mind, to the actual knowledge and to the working data necessary for learning what certain pavements cost under certain conditions, and consequently what pavement was the best one to place under known conditions of traffic.

I might say that a number of counts of traffic have been taken in this city and in other cities, and the American Society of Municipal Improvements, which is engaged in discussing and studying much the same questions as this society, has this year appointed a committee to obtain as many as possible of these counts or censuses of street traffic of various cities in order that an intelligent study may be made of street pavements, taking into account the traffic. When that society met in the City of Erie, three weeks ago, I had the pleasure of passing through some fine streets. The City Engineer had furnished the delegates of that association with cards describing the pavements traveled over; as—such a street, "asphalt pavement laid twenty-seven years ago—fine condition"; such and such a street, "pavement laid twenty-three years ago, about one-third has been replaced," etc. Nothing was said of how much use had been made of the pavement. There was just about enough traffic on these old pavements to keep the asphalt pavement ironed out and smoothed out. A little traffic is a great deal better than none at all. If he could have made each one of these statements read, "asphalt, 27 years old, traffic so much per day," the statement would have meant something; as it was it meant very little at all. I hope Mr. Tillson's desire for a traffic census will be carried out in order that we may have an intelligent study of the durability of pavements.

In speaking of pavements of various kinds and the durability of large stone blocks used, a gentleman once said, "Look at the old streets laid by the Romans—they have lasted for centuries." Another answered: "Yes, but you will have to dig three feet to find them. Any pavement will last if the street is three feet under ground." There are other conditions beside the nature of a pavement which affect its life.

Another point in Mr. Tillson's paper, which was also remarked on by Mr. Lewis, was the matter of paying for the pavement. Both gentlemen touched upon the matter of compelling the property-owners to pay the full cost of the pavement in front of their

property, even when the use of that pavement was largely by, and for the benefit of, those who traveled over it rather than those who lived facing it.

In some cases the more expensive pavement is really less desired by the people whose property faces on it than the less expensive would be. Some time ago a boulevard was built in the City of Newark, and an improved pavement was put on it, so that a great deal of driving took place on this boulevard. The residents along this boulevard were being assessed for the cost of this improved pavement, whereas, as a matter of fact, three-fourths of them would have liked to protest against having it turned into a thoroughfare; and yet they were being assessed for an extra expensive pavement so that teams by the thousands would pass in front of their houses, when they would rather not have had them pass at all, with the dust and other objectionable features.

It has seemed to me for some time that a method might be devised, and I believe it has been adopted in one or two small cities, somewhat similar to one method employed for paying for sewers, that is, on the assumption that each property-owner required for his own use a pavement which was simply proper and adequate for bringing to his front door delivery wagons, his own carriage or automobile, or such light traffic as was necessary for the purposes of himself and neighbors. That usually means the least expensive pavement. If any more expensive pavement is desired or needed, not because of his requirements, but because of those of the people generally throughout the city, the public at large should pay for that additional durability and additional expense. The principle then would be to have each property-owner pay for the pavement in front of his property a sum representing the cost of the least expensive pavement adequate for that city. In New York we will say that would be an asphalt pavement; then let each property-owner pay for the cost of an asphalt pavement in front of his property. If a stone block pavement is needed, then let the balance be paid by the public in general. Thus each man pays for the value which he gets out of the pavement and the public at large pays for the additional value made necessary by the public use of that street. I offer that as a suggestion, but it seems to me at least worthy of consideration; it has received consideration in smaller cities, although I do not know if it has in the City of New York.

HENRY W. VOGEL, M. M. E. N. Y.—There seems to be considerable stress laid on the financial side of the pavement problem. The tendency should be to assess directly on the abutting owner the cost of paving and repaving streets; every owner would then constitute himself an inspector and would jealously guard against the tearing up of pavements by city departments or corporations.

The value of property on a street in a large municipality depends to a great extent upon the number of people that pass to and fro on that street. Fulton Street, east of Broadway, was a much more important thoroughfare when ferries were the only means of access to Brooklyn, than it is at the present time.

Another point that is in favor of having the property-owner pay for the repaving in front of his own property is that when such repaving is paid from a general fund there is a possibility of having certain streets repaved that do not require it as much as more important thoroughfares. I am quite sure that the owners on an important business artery like Fifth Avenue would gladly pay for repaving if the existing pavement were in a condition to interfere with the trade on the avenue.

Improvements paid for by assessments obviate the necessity of issuing corporate stock, and greatly simplify the debt problem of the City.

EDWARD A. MILLER, M. M. E. N. Y.—I would like to ask Mr. Tillson one question as to asphalt pavements in general. I understood him to say, that the best was the cheapest. Why is not the European rock asphalt used on City streets and avenues where the grade will permit, as in my opinion, it outlives any of the other asphalts?

The Park Department has used this powdered rock on Cathedral Parkway, between Seventh and Eighth Avenues, as also on the Fifty-ninth Street and Fifth Avenue Plaza, and has found that the maintenance cost is insignificant.

I simply call attention to this fact as the maintenance question on pavements seems to be of considerable interest.

GEORGE W. TILLSON, M. M. E. N. Y.—In answer to that, Mr. President, I would say that for quite a number of years, in the asphalt specifications, there was a provision made for the European rock, and in Brooklyn we laid a few streets with this material, but it has always been considered that an asphalt pavement was an asphalt pavement and that you could not distinguish between the two. That is, you would have to advertise for an asphalt pavement and allow the American asphalt to compete with the European. It is a well-known fact that the European asphalt cannot successfully compete with the American. In the case of the European asphalt the entire asphalt surface has to be brought from Europe. In the case of American asphalt, the only part of the pavement that has to be transported is the asphalt itself which is only about ten per cent. of the pavement. I doubt whether it would be advisable to advertise for the American asphalts and the foreign asphalts as separate and distinct propositions. I agree with what Mr. Miller intimated that the European asphalts are better, as far as service is

concerned, than the American, but, as stated, on the steeper grades they would give more trouble; as the foreign asphalts are made up of limestone which has been impregnated with bitumen and there is enough of the limestone in it to make it slippery. In my judgment, there is no question that the foreign asphalts would give much better service and require much less repairs than our American asphalts.

WILLIAM R. PATTERSON.*—Gentlemen of the Society, I assure you that I am not going to discuss engineering problems,—that is out of my line, but thanks to the points that have been so fully developed by the author, there are one or two items which are particularly interesting to me.

In regard to the corporate stock, of course, every one agrees with Mr. Tillson,—as far as that is concerned they have agreed with him for a great number of years, the only point is to get some one of moral courage enough to put a stop to it. The situation is simply this: the problem of running a municipality successfully seems to be the problem of keeping the tax rate down, and the present method is to pay everything out of corporate stock that you possibly can, and let the rest go on appropriation. It is done all along the line. It is being done this year and the way it looks now it will be done next. Somehow we cannot get up to the point not to take things out of corporate stock. As most of you know, it was a short time ago when we were buying napkins and pillow cases, and only quite recently fed horses out of corporate stock. The problem is for you gentlemen to bring your influence to bear upon the present administration to give it courage enough to say to the taxpayer, "Up goes the budget the way it ought to go."

Now as to the maintenance—I confess that I have been walking along looking for fires. I wish that we could get some plan to make the owner of a house have the least bit of interest in the pavement in front of his property. Somehow the Brooklynites never learned to build fires on the pavements, yet, in Manhattan we have it done nightly. I do not know what period of training they must have gone through in Brooklyn, but they do not build bonfires. Our problem in the maintenance work is to have the house-owner take some interest in the pavement. At the present time in Manhattan he has practically none. You can walk along the street any day and you have the opportunity of stamping out three or four fires.

It seems to me that we might develop a traffic coefficient, as I call it. That is, some plan whereby both maintenance and repairs of pavements should be taxed up against the abutting property, the amount of that tax to be upon a ratio based upon the character of the traffic of that immediate vicinity, that ratio to express the

* Assistant Commissioner of Public Works Borough of Manhattan.

proportion of wear upon the streets due to local conditions and that due trucking for longer distances. Whether it is feasible, you probably know more about than I, but those are the things at least in the municipal situation that we ought to meet.

Finally and lastly—the segregated budget. I confess that I am in favor of it, not on account of dishonest men, but in behalf of a definite plan for the work of the City. Not because it will keep you from charging to a special fund a whole lot of maintenance, that history says at one time was charged to these funds, but by definitely limiting funds to certain purposes we will force the municipality to get down to a definite system and record that will give us plan for guess, and accurate statements instead of engineering judgment. I confess that I prefer the accurate statement to the engineering judgment when it comes to dollars and cents, and if by the segregated budget we can force a more accurate accounting, a more careful system of cost record, then I think we have gone a long way toward bringing order out of chaos. I do not think the segregated budget has anything to do with the question of honest or dishonest officials.

ARTHUR S. TUTTLE, M. M. E. N. Y.—Dr. Patterson's remarks relative to the moral courage needed on the part of those responsible for our City Government to meet a situation requiring a breaking away from an old policy along lines which will result in increasing the tax levy, reminds me of the appointment two years ago by the Board of Estimate and Apportionment of a Committee of Engineers with instructions to investigate and revise the estimates which had been submitted for the 1909 budget as representing the amount required for maintaining and repairing the highways in the various boroughs. This committee was given less than two weeks in which to do its work and only very meager data on which to base its conclusions. It endeavored to solve the problem by ascertaining the number of units of work required and the probable cost per unit, and also the amount required to place the areas already paved in such a condition of repair as to make the unit cost for maintenance properly applicable. This was clearly a logical method of procedure and one which could not be challenged. From the information which could be collected along these lines in so short a time the committee was unanimous in its belief that the departmental estimates originally presented, and which amounted to about $5 530 000, should be increased to about $6 600 000 if the ordinary maintenance work were to be properly performed and if the extraordinary repairs as reported by the various borough representatives were to be provided for and as believed to be needed in order to put the pavements in good condition to start with. As has been intimated, propositions which will increase the tax levy are always

objectionable, and particularly so at the time when the budget is under consideration. The report of reference proved no exception to the rule and was promptly referred back to the committee with directions to revise it in such a way that the total to be apportioned among the boroughs would not exceed $3 540 000, or an amount slightly greater than that allowed for the preceding year.

Nearly two years ago I analyzed the financial side of the repaving problem as applied to the entire city, and the results, although obtained under an entirely different method from that followed by Mr. Tillson, so closely agree with his that they may be worthy of consideration.

Allowing amounts ranging from $50 000 to $56 000 per mile as representing the cost of repaving in the various boroughs, the corporate stock issues authorized for this work between January 1st, 1898, and January 1st, 1909, with an additional allowance for what was estimated to be the special repair needs at the close of the latter year, indicated that 4.7 per cent. of the entire paved area had to be relaid annually, this representing a life of about twenty-one years, or three years more than estimated by Mr. Tillson. The records of original improvements authorized or requested during the same period was found to represent an average annual increase in the mileage of 2.1 per cent. At that time I estimated that it would be safe to assume that a pavement properly laid would last about twenty years, that the past ratio of annual increase in paved area would be continued indefinitely, and that the average cost of repaving might be estimated at $55 000 per mile. The forecast then made was limited to the next fifty years, but for the purpose of bringing out the ultimate magnitude of this item of expense we may properly consider the entire development of the city.

On the basis of block dimensions of 200 by 700 ft., with streets and avenues having widths respectively of 60 ft. and 80 ft., one acre of city area would require 0.04 mile of pavement. Assuming that the city area is 200 000 acres, that repaving will average in cost $55 000 per mile, and that five per cent. of the mileage will have to be relaid each year, the following results are obtained:

Total ultimate mileage of pavement...	8 000
Amount of corporate stock ultimately required annually for repaving...	$22 000 000
Total amount of corporate stock for repaving which ultimately will be continuously outstanding.....	$1 100 000 000

For the total capital involved and for which corporate stock will be issued if the present policy is adhered to, it may be noted that the actual value of the tangible asset is only $440 000 000, all of

which was originally paid into the treasury through assessment on the abutting property.

Again, assuming interest charges and sinking fund accumulations at the rate of four per cent., it will be ultimately necessary under the present method of financing this work, and in addition to the $22 000 000 raised each year through corporate stock, to provide annually in the tax levy:

For interest charges.....	$44 000 000
For sinking fund.....	7 205 000
Total.....	$51 205 000

The present mileage of pavements may be roughly estimated as about 1 800 miles. On the basis of the annual increase already noted, the ultimate development will be reached in 1982, or a date not so far distant as to justify us in not giving the startling outcome serious consideration. For many years past it has been the practice to allow $3 000 000 as representing the annual repaving needs, but on the basis of the data here presented it would appear that to fully care for the present work an allowance should be made of about $5 000 000 and that the present insufficient bond issues will later have to be made up by abnormally large appropriations or that the pavement will not be properly maintained.

With insistent demands from all quarters for improvements of such great magnitude as to require the exemption from the limitation placed upon the city debt of the bonds issued for certain undertakings in order to permit of new ones, the fate of a proposition to increase the Repaving Bond Account as needed to make up for past shortage and to meet future requirements does not seem uncertain, nor does the attitude which will be assumed by future capitalists who find that repaving bonds represent in actual value an improvement which has a life of only two-fifths of the period for which they are issued. Personally I have no doubt but that time will bring the repeal of the existing law which practically prevents the levying of an assessment for repaving, and the provision of power to call upon the benefited property-owners to pay for improvements of this character by direct assessment. A thorough understanding of repaving finances on the part of the members of this Society will do much to hasten the day when the present practice will be changed.

WILLIAM H. CONNELL.*—We are making some experiments of bituminous macadam pavements, which we will lay under the amendment to the Charter as preliminary pavements. President Miller was confronted with quite a problem when he took office in the Bronx. There were a number of streets that had been recently regulated and

* Assistant Commissioner of Public Works, Borough of the Bronx.

graded, and the property value was not sufficient to warrant an assessment for a first-class pavement. The debt limit was so closely approached,—and what surplus money the City had was apparently needed for subways—that the Board of Estimate and Apportionment shut down on funds for macadamizing those streets. The custom in the past has been to macadamize most of the new streets regulated and graded. President Miller presented a bill to the Legislature amending the Charter, providing for a preliminary and a permanent pavement, the preliminary pavement to be assessed on the abutting property, and the assessment for the permanent pavement, minus the assessment for the preliminary pavement, to be assessed on the abutting property when the time should come to lay the permanent pavement. We have not laid any pavement of this description this year, the bill only having passed recently, but we are laying a strip of experimental bituminous macadam pavements consisting of about eighteen different styles of pavements, differing in method of construction and binders, the sections varying from about 150 to 350 ft. in length. Some of them are being laid by the penetration method, but most of them by the mixing method, using different binders, asphalt, asphalt and tar, tar and some patented pavements that largely consist of asphalt and asphalt and tar. These pavements are now being laid on White Plains Road, just north of Boston Road, and any persons interested may look them over. We are keeping very accurate cost data and intend to take a census of traffic, so as to have our records complete, and the President's intention is, as far as possible, to use this experimental strip as a basis for the selection of bituminous pavements to be laid as Class B pavements, provided for in the amendment to the Charter last spring.

JOHN T. FETHERSTON, M. M. E. N. Y.—In spite of the fact that the segregated budget has tended to control expenditures better than the older lump sum system of appropriations, the speaker believes that it is based upon false principles, in that it neglects the results to be obtained through the expenditure of funds, and tends to inefficiency on the part of city employees. An adequate discussion of this question to-night would take too much time, but to most engineers there would seem to be little doubt that the negative effects of the segregated budget will soon give way to a more enlightened, progressive policy in which heads of departments will be held responsible in reality for results produced as shown by work cost records, and that in future for most departments, appropriations will be based upon cost data and work requirements.

SAMUEL C. THOMPSON, M. M. E. N. Y.—I do not know that I can add anything to the discussion of the paper, but one point has been brought out that should be further elaborated, viz., the

question of increase in cost of the original pavement *vs.* maintenance. In the Bronx, as well as in many other sections, the mistake appears to have been made of using a specification that reduced the first cost of pavement by allowing a wider joint and rougher surface than should have been permitted, and neglecting, to a degree, the subsequent maintenance cost. The result has been that the pavements have not remained in the desired condition, and it is believed that getting better made blocks will tend to a longer life of the pavement as well as produce a smoother, and consequently less noisy surface under traffic.

There has been up to the present time occasion to take up the roadway of various streets when blocks have been worn long enough to become rough and uncomfortable. These blocks, when of sufficient size, have been cut in two pieces, dressed smoothly, and a new head put on them, resulting in closer joints, which were grouted with cement filler, giving a comparatively noiseless granite pavement. Quite a considerable area has been treated in this way during the last year, but a sufficient length of time in service has not elapsed to determine final conditions, though all indications seem to point to satisfactory results.

With more attention paid to the dressing of the block a much quieter granite pavement than customary in the past can be produced with only a slightly increased initial cost, but with a materially reduced maintenance expense, and a great reduction in noise under traffic.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 60.

PRESENTED NOVEMBER 23D, 1910.

SOME PROBLEMS IN SEWAGE DISPOSAL OF NEW YORK.

BY WILLIAM M. BLACK.*

WITH DISCUSSION BY

ARTHUR S. TUTTLE, RUDOLPH HERING, EMIL KUICHLING, ALLEN HAZEN, EARLE B. PHELPS, A. PRESCOTT FOLWELL, GEORGE C. WHIPPLE, EDWIN J. FORT, KENNETH ALLEN, GEORGE T. HAMMOND AND WILLIAM M. BLACK.

In the treatment of the various problems of municipal engineering met in the administrative work of the government of Greater New York, with its huge population, increased by the daily influx of commuters and visitors, with the many and diversified interests and with the wide influence, direct and indirect, over the country and the world at large which the regulation of those interests exerts, each problem should be considered with reference not only to the local conditions at the point where work is immediately desired, but also with reference to its relation to like needs and similar work in the city, the State and the nation.

New York Harbor is the *raison d'être of* New York City, and of its neighbors within a mile radius. In the comprehensive report on the pollution of the harbor waters, submitted on April 30th, 1910, the Metropolitan Sewerage Commission has wisely included in its discussion the measures necessary to be taken over an area of about 700 sq. miles in the States of New York and New Jersey,

*Colonel, Corps of Engineers, U. S. Army.

within the limits of 20 miles of the City Hall, Manhattan, covering areas from which the natural drainage is concentrated in New York Harbor. More recent investigations have shown that even these wide limits are not sufficient and that the waters of the Hudson reach these limits in a highly polluted condition, so that for its own protection the City of New York should endeavor to compel the various communities along the banks of the Hudson to take such measures as may be necessary to preserve the purity of the waters of that stream.

Aside from trade wastes, the greatest agency, if not practically the only one, tending to pollute the waters flowing through a densely populated area, is sewage. In their natural state, fresh-water streams have in solution, at a temperature of 32° Fahr., 6.38 grains of oxygen per cubic foot, and at 68° Fahr., 4.04 grains. The salt waters of the ocean contain at the same temperatures 5.10 and 3.29 grains respectively per cubic foot. The effect of pollution by sewage is a reduction of this dissolved oxygen. When the quantity left in the waters falls below 70% of the saturation value, major fish life begins to disappear; when below 50%, the condition of the waters begins to be harmful to human health. This condition is evidenced in increasing measure as the remaining dissolved oxygen is reduced, by a discoloration offensive to the eye and by the formation of gases offensive to the smell and destructive to the paint on vessels navigating therein. The exact limit at which any one of these offensive conditions may begin cannot be accurately fixed, since that limit will vary with the temperature and with other conditions. It is generally assumed that for safety to human health the oxygen contents of any body of water should not be reduced below 50%, and it is probable that to insure the preservation of major fish life the reduction should not go below 70 per cent. In this connection it may be observed that since the most important of the food fishes which formerly swarmed in our waters make periodic migrations between the sea and the fresh waters, a screen of polluted water may be as effective in preventing such migrations as would be the pollution of the entire stream.

The composition of sewage varies in each locality, depending on local conditions. Numerous analyses have been made of the sewage of various cities and it has been possible to deduce the composition

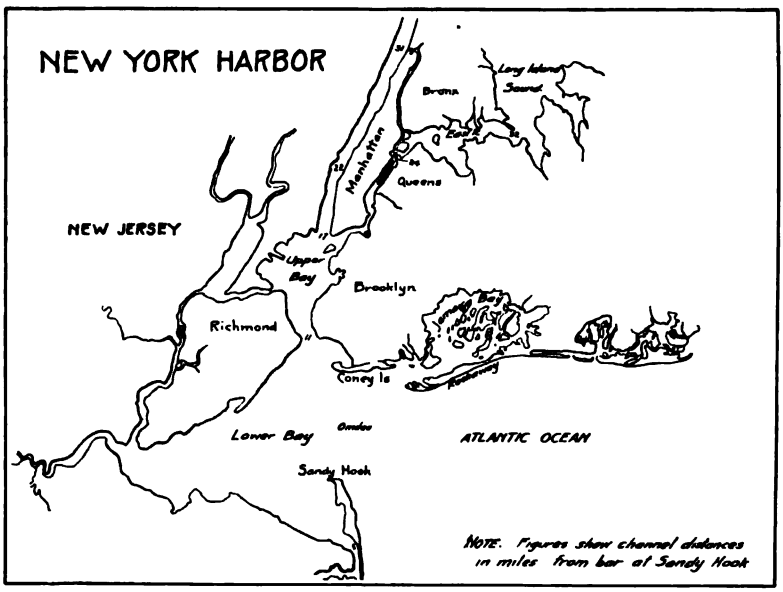
of what may be termed average American sewage, which deduction may be used in a general discussion of questions of sewage disposal in the absence of specific information. Broadly speaking it may be said that for reduction to a stable form each million gallons of sewage will require the consumption of about 1 950 lb. of oxygen under summer conditions. You all know well that this reduction of sewage to a stable form and the disposal of the resulting solids in the most economical and advantageous manner is the problem presented in all questions of sewage disposal and that such reduction, however made, is a process of oxidation.

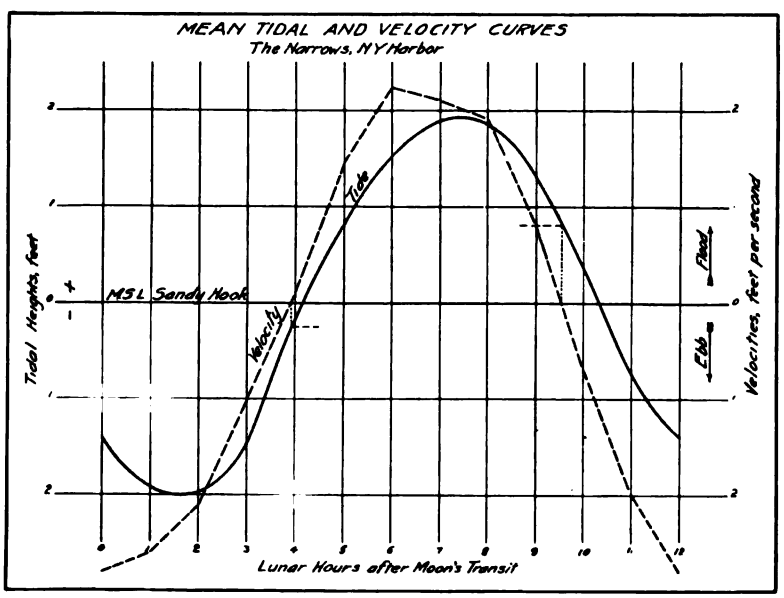
It is only within recent years that this problem has been attacked by scientific methods and even yet the exact processes through which the sewage passes in its reduction to a stable form are not accurately known; nor is it accurately known what are the agencies acting in these processes. In the natural reduction of sewage the best evidence would go to show that the action is partly strictly chemical, if such a term may be used, and partly through the help of bacteria. Where the population of an area is scanty and widely scattered, human waste can be disposed of safely by a simple removal from the dwelling. It was not until 1847 that removal by water carriage was first adopted, and then in London. This method proved so economical and convenient that it was extensively followed and, until recent years, a city provided with sewers which discharged outside of its limits, generally into the nearest body of water available, was considered to be served sufficiently to meet all sanitary requirements. Still more recently, with a large population, it was found that this method might be a cause of harm to other communities, and now it is recognized that it may be harmful to the community itself.

To-day water carriage is practically the universal method employed to convey sewage from the point of supply to the point of disposal, and almost all of the processes in use for safe disposal presuppose such carriage.

The discharge of water-carried, unpurified sewage into a body of water produces three objectionable results, viz., a deposit on the bottom, a discoloration of the water surface accompanied by more or less noxious odors, and a reduction in the dissolved oxygen of the water, producing more or less pollution.

PLATE 56.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BLACK ON SOME PROBLEMS
IN SEWAGE DISPOSAL OF NEW YORK.





The fine dotted lines show stages of tide at which the current direction changes.

It is estimated that each million gallons of ordinary American sewage contains about 4 cu. yd. of solid matter, of which about two and a half are in solution and one and a half in suspension. When the sewer is used for storm-water drainage as well, this volume is increased to an extent dependent on the condition of the area drained and the intensity of rainfall. After the streets of the City of Havana had been cleaned in 1899, there was a noticeable change in the appearance of the Harbor. Excepting towards its head, where certain bad local conditions existed, the harbor waters in appearance differed little from those of the lower Bay of New York, and without the drift which is now permitted to mar the latter Bay.

Regarding the solids of the sewage proper only, the annual deposit from a population of 1 000 000 persons, it is calculated, would, if spread over 1 sq. mile, amount to about 0.08 ft. When the washings of city streets are added this volume is greater. To-day, in New York an effort is made to collect at least a portion of such washings in the catch basins at the sewer inlets. In spite of this precaution periodic dredging is required in the slips into which the greater part of the solids is deposited. The cost of removing the materials collected in the catch basins is estimated at $1.50 per cu. yd. The cost of dredging the slips varies from 13½ cents to 20 cents per cu. yd. A comparison of these figures is interesting. Were it not for the pollution produced in the waters, it seems clear that the cheapest means of disposing of the solids of sewage would be to permit their deposit and to remove them by periodic dredging.

The second result mentioned, discoloration at the surface and the formation of unpleasant odors, is well exemplified in Boston Harbor. At Deer Island Light, 60 million gal. of sewage are discharged with continuous flow per day. The current velocities in the harbor at the point of discharge vary from 1.3 to 2.6 knots per hour. The discharge is visible on the surface for 1¼ miles. At the Moon Island outlet, sewage is discharged at the beginning of each ebb with an average volume of 88 million gal. per day. At the time of discharge an area of as much as 2 000 acres is at times covered with sewage. Both the Deer Island and the Moon Island outlets are practically at the water surface. At the Nut Island outlet the discharge is at a depth of 30 ft. at mean low water. The

sewage rises promptly to the surface, but a smaller area is covered and the sewage disappears more quickly than at the other outlets. A marked local improvement, especially in the odors given out, was made in the case of several of the Havana sewers by submerging their outlets 6 to 10 ft. below the water surface.

The lower specific gravity and higher temperature of the sewage causes it to rise rapidly to the surface when discharged into water, especially when discharged into salt water. There, too, the marked difference in color makes the sewage more conspicuous. The conditions thus formed cause a local nuisance, which while probably not injurious to human health is certainly offensive, which should not be permitted in any occupied or much traversed part of the harbor. In the design for the Passaic Valley Sewer outlet, the main sewer at its end is divided into a number of branches radiating horizontally. Each branch is provided with small outlet pipes, each set so that the sewage will be discharged through two orifices across the harbor currents in small volumes at a depth of about 40 ft. It is hoped that by this means the sewage, which is to be sedimented and strained before discharge, will be so quickly and thoroughly diffused through the harbor flow as to cause no surface appearance.

To investigate this subject of diffusion at discharge, Prof. Phelps and the writer constructed a small model, in which a partial diffusion of the sewage and a lowering of temperature is effected before discharge by means of the well-known phenomenon of the tendency of a heavy liquid to underrun a lighter one. In this model the tank is filled with water of the specific gravity of sea water. Into it is led a sewer pipe expanding at its bottom into a horizontal pipe of larger dimensions, provided with baffle plates in its upper segment. By discharging a colored liquid of the specific gravity of sewage through the pipe, the underrun and mixing can be seen. Samples taken at the outlet show that at discharge the sewage has been diffused through somewhat more than its own volume of the tank water (sea water). The experiment demonstrates the action. Further experiments and calculations should show the best relation between the diameters of the sewer and outlet pipe for a given flow and also the best number and arrangement for the baffles. There would be a tendency for deposits to

form near the point where the sewer enters the outlet. Such deposits might be removed sufficiently by periodic flushing either with storm-water flow or by special apparatus, or the removal can be otherwise provided for.

The effects of the pollution of the water are mentioned elsewhere in this paper. It should be noted here that no matter whether the sewage, with its unstable organic contents, is exposed to air, soaked into the earth, or discharged into water, its decomposition goes on, more or less rapidly, and the resulting stable form is about the same. Old covered cesspools in Havana, when opened for cleaning, seemed filled with inoffensive garden mould. Old deposits in a harbor have the same general appearance. Old septic tank sludge is much the same. Too ardent advocates of sewage purification sometimes make mistaken statements on this point.

The processes used for sewage purification may be summed up as follows:

Sedimentation;
Screening and straining;
Chemical precipitation.

The various systems of oxidation through natural agencies comprise:

Broad irrigation;
Intermittent sand filtration;
The use of contact beds, and
Trickling or percolating beds.

Sedimentation, straining and screening are methods by means of which a portion of the coarser parts of the polluted materials are removed by mechanical means. These processes require extensive tank surfaces, and a mechanical apparatus of a more or less simple form, which entail a practically constant supervision and a necessity for the removal of large quantities of sludge. They may be counted on to remove about 50% of the suspended matter in the sewage, or about 20% of the total organic matter in a putrescible condition. It is this system which it is proposed to use for the purification of the outflow of the Passaic Valley sewerage system. The works are to be located in the Newark Meadows.

In speaking of the results obtained by the chemical treatment of sewage, Kinnicutt, Winslow and Pratt in their work on "Sewage Disposal" state:

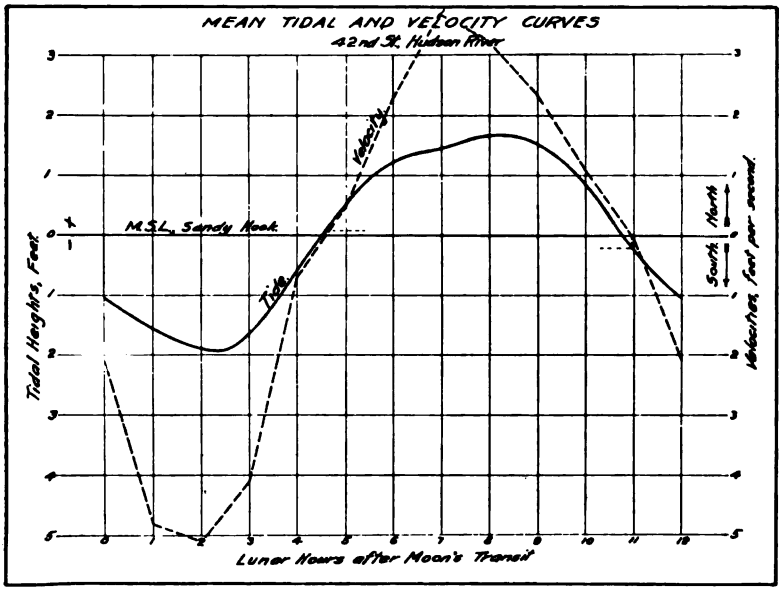
"The chemical treatment of sewage removes practically only the suspended solid matter. Under favorable circumstances and with careful work a certain percentage of the soluble organic matter may be carried down, but there is no workable precipitation process which will give a nonputrefactive effluent and chemical precipitation must be considered merely as a method of removing from the sewage visible solid matter."

They show that for two American cities in which this process is used, about 80% of the suspended solid matter is removed from the sewage.

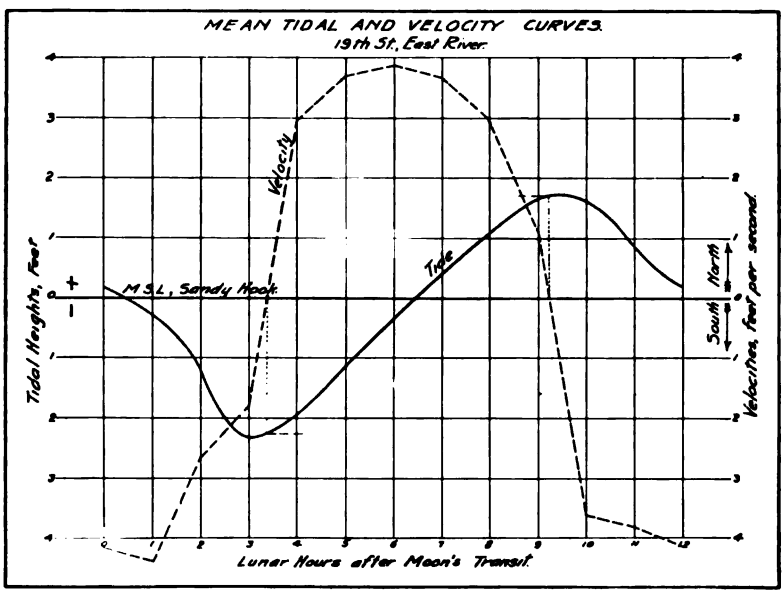
In the septic tank treatment mineral matter in suspension is removed by sedimentation and organic matter is liquefied. The effluent is, however, highly putrescible and this process cannot be considered a suitable one for sewage disposal, unless the volume of water into which the effluent is poured is so great as to be able to care for this effluent without an undue reduction of its dissolved oxygen. The liquefaction mentioned is of value in that when such an effluent is discharged into water, it is the more quickly disseminated and lost in the general flow.

Of the purification methods employing natural agencies, the sprinkling filter or percolating bed is probably the most advantageous and efficient. The authors above quoted, speaking of the comparative cost of trickling filtration and of other processes said: "In general it seems clear that treatment on trickling beds is likely to prove the most economical method of purifying sewage to the point of organic stability where the presence of suspended matter is not an objection." They state that an acre of trickling surface can purify the sewage from a population of at least 10 000 persons. This figure might be increased to 20 000. This statement, while giving strong testimony to the efficiency of the trickling bed process, shows that for a large population the area of beds required would be very considerable—one acre per 20 000 persons. Practically the area required is much greater since the odors from these beds make them a very undesirable neighbor, so as to render property in their vicinity of little value for residential or business purposes. These necessities make this process practically inapplicable to a city

PLATE 57.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BLACK ON SOME PROBLEMS
IN SEWAGE DISPOSAL OF NEW YORK



Fine dotted lines show stages of tide at which the current direction changes.



Fine dotted lines show stages of tide at which the current direction changes.

with a large population at a distance from areas of waste land, such as are the conditions in New York. In this process the essential features are a permeable bed made of indestructible materials, with interstices great enough to permit a circulation of air; a depth of bed sufficient to cause sewage trickling through it to be in contact with these materials for a time sufficient to permit the bacteria forming and working on their surface to act; and a mechanical device for sprinkling the sewage over the bed in drops which, in falling through the air, carry with them a certain amount of air and by which the sewage is poured on the bed surface at a rate which will insure that the voids in the bed shall not be filled with liquid. In practice the depths of these beds varies from 4 to 6 ft. The active agencies in the oxidation of the sewage are the oxygen in the air and the bacteria present on the surfaces. As stated above, the great obstacle to the more extensive use of these filters in congested localities is the extensive area which they require. This extensive area is needed because of the amount of inert material in the solids used in the bed and of the necessity for supplying sewage over the bed surface at a small rate of flow per square foot of surface.

If purification is required for the sewage of New York City, it is evident that any one of these accepted methods would be very costly, either in the area required, or in the cost of plant and of operation, or in all. It might be found on careful analysis of the problem that it would be more economical to collect the sewage and carry it to or near to the sea—a project of a magnitude approaching that for the new water supply.

It occurred to the writer that it might be possible to increase the efficiency per square foot of area of the percolating bed and to devise a plant for sewage purification of a more compact form, which would do its work through the same agencies, but for which a smaller area would be needed, and which therefore might be used under the conditions of a congested city; in short to further improve the percolating bed by reducing the relative volume of inert material and increasing the volume of sewage under treatment.

Under the direction of Mr. Nelson P. Lewis, Chief Engineer of the Board of Estimate and Apportionment of the City of New York, certain experiments along this line have been carried on by Prof.

Earle B. Phelps and the writer at the Twenty-sixth Ward Disposal Plant in the City of Brooklyn and also in a small experimental plant at the Massachusetts Institute of Technology Sewage Experiment Station in Boston, Mass.

In the apparatus used the sewage was confined in a septic tank for a period of five hours, from which it flowed into another tank containing racks of slats formed of common lath set, vertically and horizontally, about one inch apart and staggered in both directions. The surfaces of the lath were at an angle of about 45° to the horizontal. Along the bottom of the tank were laid parallel lines of pipe perforated with ⅛-in. holes and covered with fine mesh copper gauze similar to the lowest section used in a driven well. This pipe was connected with an air compressor. This arrangement gave throughout the body of the tank a very large surface for the development of bacterial growths and served to improve the diffusion of the air supply from the pipes at the bottom, and delay its passage in its upward flow. The time of flow for sewage through this tank was about 1½ hours. About 0.1 cu. ft. of air was supplied per gallon of sewage. About 2% of the oxygen of this air was absorbed in passing through the tank. Experiments showed that the economy of the process increased with the depth of the tank as far as a depth of 24 ft., the limit attained in the experiments. As will be observed, the apparatus differs materially from the Waring filter, in which air under pressure was used in sewage reduction.

The details of the results of the experiments are not yet ready for publication. It can be said now, however, that it can be shown that by this process sewage can be purified in measure sufficient for safe discharge into the waters of New York Harbor with a plant occupying less than one-sixth of the area required for percolating beds and at a low cost of operation—and that such plants can be located along the water-front of a city, with a number of units operated and handled from a central station. The plant is not elaborate, and the principal item of expense is that for providing the air. This item is increased or diminished directly with the variations in the necessity for purification, as between summer and winter conditions, for example.

The present necessity for the purification of the sewage of New York is a question which is warmly debated. It is known that

certain sections of the harbor are now in a condition which may be properly regarded as a public nuisance.

It is further known that major fish life has been greatly reduced in quantity within late years in the harbor waters and in the Hudson River. The Metropolitan Sewerage Commission has presented a report in which such purification is strongly recommended. On the other hand, it is contended that the conditions found by the Sewerage Commission are caused by imperfect diffusion of the discharged sewage and are local, and that a more perfect dissemination of the sewage through the waters will remove them.

The writer has had occasion to make certain investigations into this question and the methods followed, and the partial results already obtained may be of interest.

The waters of the harbor of New York may be justly regarded as an apparatus supplied by nature for the reduction of the sewage of the population of its drainage area. Such a use is necessary, and advisable to the limit of the capacity of these waters.' But if this apparatus be overloaded, not only it cannot do the work required, but also it will become a menace to health, and long before that limit is attained it will be practically unfit for commerce, especially for the class of commerce which has made Greater New York—a commerce for which other cities are reaching eager hands. The establishment of trade routes and of trading centers is dependent on many conditions, and the world's history shows many examples of once flourishing ports reduced to insignificance. It will not do for any commercial center to neglect any of the conditions which tend to prosperity. The condition of the harbor is not one of the least potent of these conditions. The question is of importance and merits careful consideration and study.

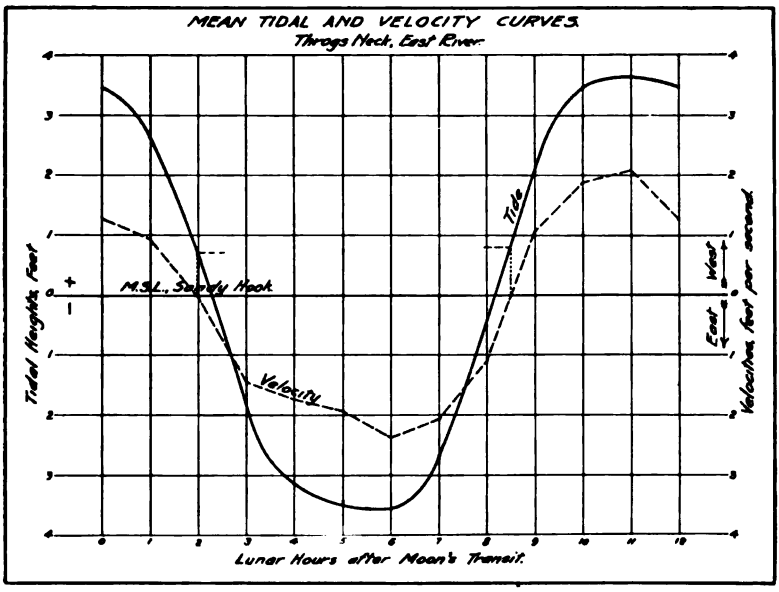
As has been stated, the discharge of unpurified sewage into the harbor has as a result, the diminution of the dissolved oxygen of its waters. When such a diminution passes 50% of the quantity of dissolved oxygen at saturation, evidences of putrefaction become manifest. Such a condition is admittedly inadmissible. If the possibility of the existence of major fish life be taken as a required standard of purity, such a standard will demand that the reduction of dissolved oxygen does not exceed about 30 per cent.

In the case of a stream having a constant flow in one direction, it is evidently easy to calculate the approximate quantity of sewage of a known composition which can be cared for by the waters with the volume of oxygen it contains over the 70% of the saturation volume, and further, to calculate with approximate accuracy the degree of purification which should be given to a greater volume of sewage before discharge.

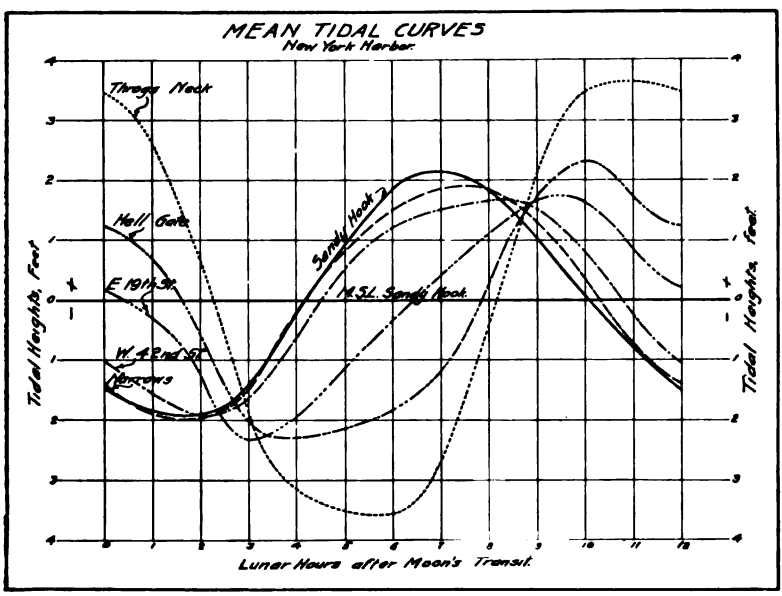
In the case of a tidal basin filled and emptied by each tide, such a computation is also comparatively easy. For example, Jamaica Bay presents such a case. There we have a basin with a tidal prism filled and emptied by each tide through Rockaway Inlet—where the channel lines are clearly defined and the current velocities in the entrance known. The capacity of the tidal prism, of the bay is shown by the volume of flood flow, and this volume as measured can be checked readily by multiplying the area covered by the average range of tide. Within the bay the entrance channel branches into several minor channels, through which the entire prism is filled and emptied. At the head of the bay there is a periodic rise and fall of the water, without current circulation excepting under wind action. The oxygen known to be available for work each twelve hours is evidently that contained in a volume of salt water equal to the volume of sea water brought in at each flood. Knowing the total volume of sewage which enters the bay in each twelve hours, the degree of general pollution can be shown.

In plans prepared under the direction of the Board of Estimate and Apportionment it is proposed that there shall be three sewer outlets into the bay, discharging one in the entrance channel, and one in each of two of the branch channels. By taking the areas of the tidal basins feeding each of the channels in the bay, with the range of tide in each basin, the volume flowing through each channel was obtained. From this and the cross-sections the mean velocity in the channels for the 6 hours of tidal flow was found. It was then assumed that the amount of polluted water remaining at low water in any channel, between the sewer outlet and the channel mouth, is equal to the volume of sewage discharged from that outlet in the period, determined by dividing the length of the portion of the channel in question, expressed in feet, by the velocity of the ebb current in feet per second. With these quantities the

PLATE 58.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BLACK ON SOME PROBLEMS
IN SEWAGE DISPOSAL OF NEW YORK.



Fine dotted lines show stages of tide at which the current direction changes.



The relative elevations of any two points in the same channel at any lunar hour will show the current direction at that hour.

percentage of sewage to tidal water was then determined for each channel and for the whole bay.

In making the calculations, the percentages of pollution at the start were taken at zero. With this assumption each flood tide will bring in water slightly more polluted than the preceding. The factor of increase per tide is a diminishing factor while the sewage flow remains the same. After calculation for from 6 to 7 tides this factor approached zero, and the condition was then assumed to represent the average pollution caused by the volume of sewage flow assumed.

Assuming a given population for the drainage area tributary to Jamaica Bay (50 per acre for the territory immediately around the bay, and 25 per acre in suburban parts), the amount of probable sewage can be calculated. The present composition of the sewage flowing through the Twenty-sixth Ward Purification Works is known. That from the other outfalls can be determined. The amount of oxygen which would be taken from the waters during the period of sewage detention in Jamaica Bay can also be calculated for each outfall. Now, from calculation already made for the assumed maximum of population it is found that the average dilution of the sewage at the sewer outlet in Rockaway Inlet would be 1 in 209; that the average dilution of sewage in the vicinity of a second outlet would be 1 in 75; and that for the third, 1 in 95. Maximum pollution at the time of change of tide for each will be greater. It is evident that the degree of purification required to maintain a standard of purity in the waters differs for each sewer line, and that economy and good administration demand that the degree of purification required for each shall be provided for, and that each presents a problem for separate solution.

In the above analysis, the increase of the oxygen supply by fresh-water flow, and by absorption from the air has been neglected. Jamaica Bay has no important fresh-water tributaries, and that factor does not enter. In a recent analytical discussion of the subject (not yet published), supported by physical experiments, Prof. Phelps has shown that the absorption of oxygen from the air through the surface of still water is too small to be considered, and that in a harbor the only causes which may be relied on for a

direct re-aeration of the water are wind action sufficient to break the surface, eddies and boils or changes of the temperature which cause a circulation between the upper and lower layers, and the direct stirring of the upper layers caused by shipping in movement. It is manifest that the amount of such a re-aeration cannot be calculated with any high degree of accuracy. Under such conditions the effects of re-aeration must be counted on only as a factor of safety.

An analysis for New York Harbor proper can be made similar to that given for Jamaica Bay, though the tidal conditions in New York Harbor make the problem much more complex.

In order to understand these tidal conditions, the following should be borne in mind: Tidal currents are developed in shoal water as a result of the tidal wave; but, due to the living force of the water in motion and the differences of velocity of the tidal wave movement, and that of the currents created by it in inclosed tidal waters at any one point, there is ordinarily a marked difference in time between the time of high and low water, and the time of the changes of direction and of the maximum and minimum velocities of the induced currents. In a river like the Hudson, the true tidal wave, which follows the moon in its passage around the earth, stops at the Sandy Hook entrance, but the wave motion is propagated up the Hudson at a rate varying with the depth until stopped by the dam at Troy. Between Sandy Hook and Governor's Island, this wave movement has a velocity of about 20 miles per hour. The maximum current velocities produced are from 3 to 4 miles per hour. Between Governor's Island and Spuyten Duyvil the wave velocity is about 19 miles per hour; the maximum current velocity for flood and ebb, respectively, is about 2.3 and 3 miles. Further up-stream the velocities per hour of the wave propagation are approximately: Spuyten Duyvil to Peekskill, 18 miles; Peekskill to Hudson, 15 miles; Hudson to Troy, 10 miles.

The harbor currents are caused by two tidal waves, the crest of one of which reaches Sandy Hook at 7½ hours after the time of luner culmination, while that of the other arrives at Willetts Point through the Sound 3 hours later. The induced waves meet and interfere over the two routes between these points, one via the East

River direct, the other via the Hudson, Harlem and the East Rivers. Some of the slopes in the river channels produced by this movement are shown on the accompanying plates (see Plates 56 to 59). The circulation of the water in the harbor is caused by these currents, plus the fresh-water discharge of the streams tributary to the harbor. A preponderance of volume of flow to the south through the East River, and to the north through the Harlem, added to the fresh-water discharge of the Hudson, causes a resultant movement of the waters toward Sandy Hook. This movement would carry a floating object through the East River from Willetts Point to Governor's Island in about 3 tides or 36 hours; through the Harlem River from Ward's Island to Spuyten Duyvil Bridge, in ½ tide or 6 hours; through the Hudson, from Spuyten Duyvil Bridge to Governor's Island, in about 3 tides or 36 hours, and through the Upper and Lower Bays from Governor's Island to the sea at Sandy Hook in 11 tides or 140 hours (see Plate 59).

Practically unpolluted water is brought from the sea and from the Sound during each flood tide. This affords the main and almost the only supply of oxygen available in the harbor waters for sewage reduction—since the rivers have their own work from the communities along their shores. Recent observations in a cross-section of the Hudson, opposite Mount St. Vincent, taken through all parts of the section through 10 hours showed for the whole time an average pollution which had reduced the oxygen supply to 51.2% of its saturation value. The purest water found at the last of the ebb tide had its oxygen contents at 66.8% of the saturation value, while the worst, taken during the flood, showed a reduction to 39.6%.

It is evident that the various portions of the harbor are reached by sea water at varying periods after its passage over the bar at Sandy Hook, or through the Willetts Point entrance to the East River. It is further evident that the degree of pollution of the water at any one point in the harbor is dependent on the length of time the waters at that point have been in the harbor, on the amount to which they have been polluted before arriving at the point in question and on the amount of pollution received there. From this it follows that the amount of sewage which can be discharged into the harbor at different points without undue pollution

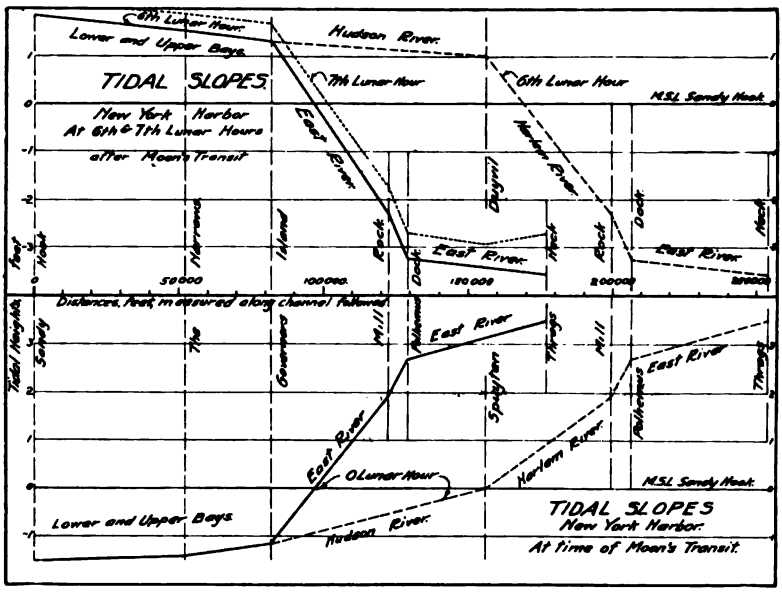
of the waters will vary, and that the economical degree of purification will also vary.

Two methods of investigation are open. One is to determine the existing pollution in the various parts of the harbor and to endeavor to find a remedy. In following this method it is difficult to determine the source of the pollution at any one point, or to differentiate in the degree of purification which should be required at different points. Even though the entire community must pay the bills, each section should bear the advantages or disadvantages which it derives from its location. A section remote from the centers of business and pleasure, but situated where its question of sewage disposal is rendered simple by proximity to a large body of unpolluted water, surely should enjoy the benefits of its location as well as the ills.

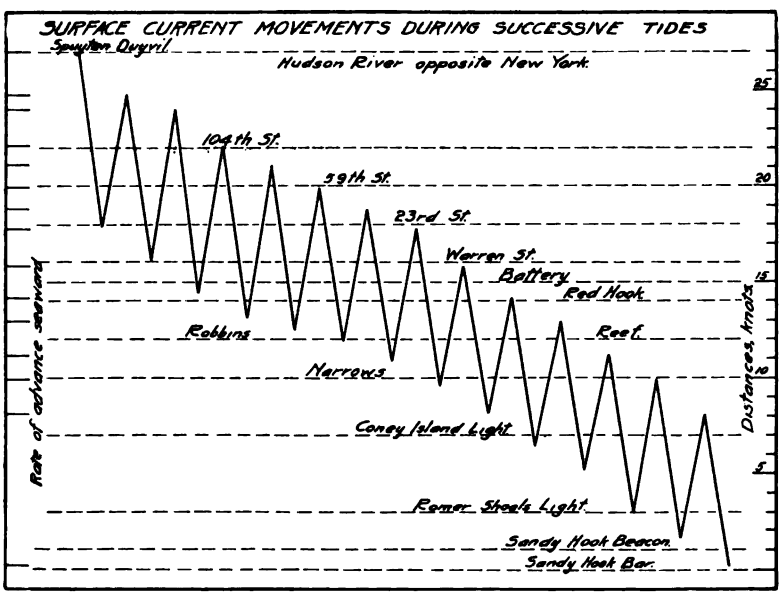
The writer deems it preferable to try to determine the amount of unpolluted water, or, if may be so called, the age of the harbor water, which a study of the tides and currents will show, may be expected in each portion of the harbor, and from that to determine how much work of sewage purification the waters may be expected to do without harm at the point. Should it be shown, then, that on account of local conditions, economy demands for any locality that sewage purification be carried on elsewhere, in order that discharge without purification shall be permissible there, the cost of the necessary work can be charged where it belongs.

A method by which such an analysis can be made is as follows: When the flood currents begin the movement takes place through the channels. From these the waters spread over the side areas—filling them to the extent of the tidal range—the main stream following the channel to the reaches beyond. Conversely, at ebb the side areas are emptied through the channels, which carry also the ebb from the reaches in rear. In other words, the movement through any reach is through the channels traversing it. Movement to and from side areas is generally from and toward the channels. At the end of ebb flow, the waters in any reach of the harbor are those from reaches further toward the ebb up-stream. When the change of current direction is coincident with the change in tidal rise and fall, the tidal prism of any area is emptied and filled by the ebb and flood flows from and into that area. When, as

PLATE 59.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BLACK ON SOME PROBLEMS
IN SEWAGE DISPOSAL OF NEW YORK.



The full line shows the slope in the Bays and East River, between Sandy Hook and Throgs Neck, at the 6th hour and at Lunar Culmination. The dotted line shows the same for the 7th lunar hour. The broken line shows the slopes between the same points, via the Hudson and Harlem Rivers, at the 6th hour and at Lunar Culmination.



in the case of the Upper Bay of New York, the flood currents in the Narrows do not begin until two hours after low water, at which time the water surface of the Upper Bay has risen 1.7 feet, the lowest 1.7 ft. of the tidal prism is composed of water which has come from the Kill von Kull, the Hudson and the East Rivers.

To determine the general conditions of the waters of the Upper Bay at the end of any given flood or ebb tide, the following computations were made: The total volume of water in the Upper Bay at any given time was computed from the charts. The tidal prism emptied and filled in ebbs and floods was also computed from the charts and tide tables. This volume for floods is the difference between the volumes passing through the Narrows during flood currents (the accretion through the Arthur Kill being negligible) and the volumes passing out of the bay through the Kill von Kull, the Hudson and the East Rivers during the same period. The gaged flow through all of these channels affords a check on this computation. Similarly, the volume at the end of ebb flow was computed. In this case, the area included between the 18-ft. contours was assumed as channel area and the remaining areas are assumed as side areas. The volumes of water contained in each were determined.

At the end of the first flood, neglecting volumes of sewer discharge, the composition of the waters of the Upper Bay will be as follows: The channel areas will be filled one-half with waters of the last tide (practically pure sea water), and one-half with waters which had been in the bay during the preceding ebb; the side areas will contain waters, two-thirds of which had been in the bay at the end of the preceding ebb and one-third filled by the last flood.

By continuing the same line of reasoning the age of the waters from earlier tides can be determined.

By representing the various volumes by letters, a general formula can be found where terms show the quantity, age, and source of the various components of the resultant volume for any tide.

Examples of such formulæ for the waters of the Hudson, between the Battery and Ninety-sixth Street, and between Ninety-sixth Street and Spuyten Duyvil, are as follows:

$$\text{Ebb}\begin{cases} C_n = .2473\, C_{n-2} + .1549\, D_{n-2} + .6684\, D'_{n-1} + .2362\, G'_{n-1} \\ D_n = .8088\, D_{n-2} + .5305\, G'_{n-1} + S \end{cases}$$

$$\text{Flood}\begin{cases} C'_n = .0132\, A_{n-1} + .4305\, B_{n-1} \\ D'_n = .0697\, B_{n-1} + .7435\, C_{n-1} \end{cases}$$

In which

B = Volume of water in Upper Bay at end of ebb;

B' = " " " " " " " " " " flood;

C and C' = " " " " Hudson, between Battery and Ninety-sixth Street, ebb and flood;

D and D' = " " " " Hudson, between Ninety-sixth Street and Spuyten Duyvil, ebb and flood;

G and G' = " " " " Harlem River, ebb and flood;

V = " " " " Hudson, above Spuyten Duyvil Creek, received in flood from lower reach;

n = a particular tidal stage;

$n-1$ = the tidal stage 6 hours earlier;

$n-2$ = the tidal stage 12 hours earlier, etc.

This question is as yet under study, and all of the quantities for the various parts of the harbor have not yet been determined to our satisfaction. The method is based on assumptions which are a question of judgment and subject to error. It can be said that at least this method is an approach to a logical study of the probable results of the movement of the harbor waters, in the commingling of those received into the harbor at different times and from different localities. In this study the tidal movements and the results of the gagings of the volumes of the flow in the harbor channels, published in the Appendices of the Reports of the U. S. Coast and Geodetic Survey, 1886 to 1888, have been used, augmented by gagings and tidal measurements made by the U. S. Engineer Department in the Harlem River and in the vicinity of Hell Gate. The available data is too meagre for a satisfactory solution of the problems. The variations in velocity, and even in direction of the currents in any cross-section of a tidal channel, make any theoretical discussion of volumes of flow of doubtful value. The actual results obtained by careful gagings in the cross-

sections alone are to be depended upon and these only as representing the conditions existing when made. For the proper solution of the problems involved, a most wise expenditure would be made in continuing further the work done under Prof. Henry Mitchell in the eighties.

The foregoing discussion is submitted as a small contribution toward the solution of a problem which is becoming more pressing daily. To-day New York finds herself in an embarrassing position. She cannot go into the courts for the restraint of nuisances created or about to be created in her harbor waters by her neighbors, with clean hands, since she herself is the worst offender, and has no greater right to the use of those waters than have her neighbors. The magnitude and complexity of the problem, physically and in the money values involved, are such as to demand the best thought and the time of all responsible for the care and removal of the City wastes, a duty of primary importance in the City government.

If thought and discussion of this subject are stimulated by this paper, its object will be fulfilled. The questions may be stated to be: How shall New York dispose of her sewage so as not to injure herself or her neighbors? If by purification before discharge, what methods are best, where shall each be applied, to what extent should the process of purification be carried at each point? How can the effluent be diffused when discharged without causing offense?

DISCUSSION

ARTHUR S. TUTTLE, M. M. E. N. Y.—One of the most important problems of the future, if not of to-day, for which New York must find a solution, is the one relating to the disposal of its sewage. Agitation of this question has been active for several years past, and we have witnessed an awakening of interest on the part of our municipal as well as State and Federal officers.

The science invoked for purification remedies is yet in its infancy, in so far as it deals with conditions such as exist in New York, and to plan purification works now for the remote future must, except for limited areas, almost inevitably result in radical amendment before such works can be completed.

Recognizing that the doctors differ as to the extent of and remedy for the present pollution of the harbor, and that conditions might be vastly improved if future plans were so prepared as to secure the most suitable natural outlets and at the same time admit of applying such purification as might now or later be required without impairing the usefulness of the work previously done, the Board of Estimate and Apportionment arranged with the author to undertake an examination of the waters surrounding New York, for the purpose of obtaining the benefit of his expert knowledge in reaching a conclusion as to how the areas now undeveloped should be drained and as to the lines which should be followed in improving existing trunks.

We are indeed fortunate in getting him to tell us something of the nature of the work which he has been doing and of the basic principles which have governed it. We are also favored with the presence of a number of the most prominent specialists in this line of work, all of whom, I have no doubt, are prepared to discuss the paper.

RUDOLPH HERING, M. M. E. N. Y.—Mr. President and gentlemen: I have made a few notes while listening to the very interesting paper of Colonel Black and thought possibly I might give you some views on two or three of the subjects with a little different aspect.

The first note was with reference to the percentage of dissolved oxygen that Colonel Black thinks should be in the harbor water in order to satisfy the conditions of our metropolis. I was surprised to hear that his figure was 70% of saturation. I think engineers and chemists often get into difficulties by not working on the same plane. Certainly this figure is not one that I could justify and endorse. The greatest metropolis of the world, London, discharges all of her sewage into the Thames, after it has deposited in basins some of its suspended matter, I do not know just how much,

and the official limit for dissolved oxygen is 30%, which is considered the figure that will preserve a clean river, with probably more vessels in it than in any other stream in the world. The tables which I saw this summer show the amount often gets down to 25 or 23%, and you cannot see anything bad about that river. I have been on it several times, down to its mouth.

At Philadelphia, the Delaware River water last summer held an amount of oxygen in solution of about 50%. The water was certainly not bad in appearance; it was not unpleasant to sail upon and it is actually used for drinking, after filtration, with no bad sanitary effects or other objectionable results. Even allowing for the slight difference between salt and fresh water, we certainly can stand 50% oxygen saturation in New York Harbor, and much less if we simply sail on it, as on the Thames.

I cannot understand the remark that the Hudson River above the upper limits of New York is in a "highly polluted condition," due to pollution above the city. I have often been up the river, but have never seen conditions to justify this description, and there is certainly no evidence elsewhere in America or Europe from which such a conclusion can be computed, barring some improper outfalls or floating sewage matter that should never be allowed to get beyond the outfalls.

Another note relates to the amount of suspended matter which gets into our sewage, and when deposited is known as sludge. The matter is of animal, vegetable and mineral origin, but the animal and vegetable only concern us at present. Most of the animal matter decomposes rapidly; some of it, like bones and hair, decomposes slowly; it is resistant. The same is the case with vegetable matter. Some of it will last hundreds of years in water and some will decompose very quickly. We must therefore discriminate between the different kinds of organic matter which constitute the sludge. They do it here and there in Europe, and it helps a great deal, not only to understand the phenomena, but to get the best disposal effects.

I wanted, also, to correct an impression regarding the Boston outfalls, alluded to by the Colonel, which are frequently spoken of as good examples of the disposal of sewage in tidal waters or in harbors. I mean no criticism by the following statement, as the ways and means of sewage disposal are in a constant process of evolution, but we could now devise a very much better method than that employed in the Boston Harbor. In the first place, the sewage is concentrated in large masses. One of the outfalls is, I think, 60 in. in diameter and discharges about 30 ft. below the surface. The sewage comes out vertically, with a velocity of three feet per second, and shoots right up to the surface. It is fresh water, and is discharged into the denser salt water.

You can readily find the outfall, because of the sewage at the surface. That is not the way we would to-day discharge sewage into salt water. The way to do it is the way Col. Black described to you, by discharging horizontally, so that there is no vertical component, and discharging by a large number of small openings extending across the current.

Europe has several such cases. Let me call your attention particularly to the city of Hamburg, on the river Elbe, which is to me one of the most interesting places to study the discharge of sewage into river waters. There the sewage is discharged practically, though not as thoroughly as the way in which Col. Black has described, as being the intention of the Passaic Valley Sewage Commission. There are several outfall sewers going into the river and discharging at the bottom at different distances from shore. Almost a million people discharge their sewage in this manner into the Elbe and you cannot see it anywhere. The appearance of the water is about like that of the Delaware River at Philadelphia, as I have several times seen it from the municipality's launches. It is always slightly turbid in both cities, partly because of the large amount of fine suspended matter in the water of every alluvial river in its lower stretches, not to speak of the washings from the bordering large cities, and partly because the water is fresh, which causes less coagulation and sedimentation of such matter than if the water is salt, as it is in both cases some miles below.

The river Elbe is kept well agitated owing to the busy harbor, which tends to hasten oxygen absorption, but more oxygen is needed than in clear water, because of the fine organic suspended matter, much of which consumes it. Remember, there is more shipping per square mile in that harbor than in any other in the world, except London, and yet the water is practically clean. The tidal range is about 6 ft. They drink the river water, after filtration of course, both in Hamburg and in Altona, which adjoins it and takes the water below the sewage outfalls of both cities, and yet the typhoid fever death rate since they filter the water is lower than the average in American cities, notwithstanding that it contains the sewage from so large a population, and the fact that all the ships are cleaned in the harbor, bearing dirt brought from all over the world. Surely there cannot be any better criteria for judging this case than the sick and death rates and the eye and nose.

I am interested to hear that we are to get some new information from Professor Phelps on the absorption of oxygen from water surfaces. That question has been much discussed in Europe. I am now thinking of Paris. I had the good fortune to be able

to visit Paris, as well as most of the other European cities a number of times, to study these sewage matters. Not a great many years ago, the river Seine, just below Paris, was black and so foul that gas bubbles were constantly coming up. At one time we estimated their diameter as two meters. I never saw anything like it anywhere else. After a flow of about 10 miles that river was fairly clean, and satisfactory for commerce. How was that purification brought about? It was partly due to sedimentation, as the river has not a swift velocity. It was partly due to oxidation of the dissolved organic matter, which could not get the oxygen from any other source than at the surface, where it was absorbed from the air. The Thames, below London, furnishes another similar case. We find oxidation of sewage, after it is discharged in a river, going on in many places, and the only source of oxygen is from the air, by absorption at the surface.

I would yet like to say a few words about the septic tank and sludge digestion. Some years ago I was employed to recommend a sewage purification system for the city of Columbus, and was retained after that at various times until the completion of the works. At the time the present works were recommended it appeared from all the evidence available, in Europe as well as here, that the proposed design was the best. Before the works were three-fourths completed, I began to have serious doubts concerning the superiority of several features of that design, prominently the septic tank. To be sure of the facts, I made a trip to Europe two years ago last summer and returned with the conviction that there had been so much progress made meantime that it was necessary to revise several of the opinions that had hitherto been held. It seemed to me that certain fundamental principles were now crystalizing on this subject, which I embodied in a few articles communicated to *Engineering News*. My opinions on what I thought should be the changes when applied to the Columbus works, were given in a discussion of the paper by Mr. John H. Gregory, engineer in charge of the work, presented to the American Society of Civil Engineers last spring.

What I think should be mentioned here to-night concerns the most important step of progress in sewage purification recently made, namely, the inoffensive sludge digestion. I first became acquainted with it two years ago last summer, and to verify the expectations, I visited Europe again last summer. This method was suggested by Dr. Imhoff in Essen, Germany, and is based on the plant built some years ago by Dr. Travis in Hampton, south of London, who separated the liquids from the solids and treated each independently without the addition of chemicals. The Imhoff method is to let fresh sewage flow through a tank at a slow velocity,

so that in about two hours from 80% to 95% of the suspended matter capable of subsiding will settle out. The matter slides through a slot in the bottom and enters a lower tank for deposit. There is no circulation of sewage in the latter. The accumulated deposit or sludge remains in the same for three to six months and is so thoroughly fermented, digested or rotted away that, when withdrawn, it is free from non-resistant, putrefying organic matter and resembles in appearance and odor humus or garden mould. It is, therefore, not in the least offensive and can be disposed of as though it were such soil. It contains but 55 to 60% of water.

I had the great satisfaction of reaching the conclusion that we have to-day a method, cheap and effective, of rendering the sludge entirely inoffensive at a small cost. The testing station in Berlin had experimented with this method for a year and found it satisfactory.

In Schwerin, Mecklenburg, I saw one of these tanks at the sewage works within sight of the castle, one of the finest in Europe. On inquiry, I found that they had never had any odor from the works, and the sludge, as elsewhere, was like garden mould. Nearly two years ago I recommended a test of this method to be made in Philadelphia, and the same results have there been reached.

Another advantage of this Imhoff sludge is that it is no longer sticky, but crumbly, and dries after three days' exposure to dry atmosphere, so that it can be spaded, put into carts, dumped and used in fields.

I also want to say something about an interesting plant in Leipsic, where experiments had been made on the action of stale sewage. It was there found that the aeration of a sprinkling filter under a pressure of ¾-in. water column actually increased the purification 50%, thus indicating a deficiency of oxygen in this filter and doubling the efficiency of the beds. I was much pleased to hear that Col. Black has done still better.

I have recommended this method to the city of Atlanta, and we will have a practical, large-scale, demonstration of the degree of its practical value inside of a year.

Just one other point. The Chicago Drainage Canal is a canal that connects Lake Michigan with the Desplaines River, an affluent of the Mississippi River. It was built to dispose of the Chicago sewage by dilution. It is a canal about twenty-five miles in length, excavated for a large part of its length through rock at an expense of something like thirty million dollars. The chief question to be answered when making the design was how much water should the canal carry to properly dilute the sewage. A careful study had to be made of conditions, not only in this country, but in Europe, to secure safe information, and not make the

channel any larger than necessary. Now that it has been built, it furnishes a most useful example from which to study various phases of the dilution question. There is no nuisance anywhere along the canal when the dilution is what was intended.

The Passaic Valley sewage distribution in the harbor was based on the Chicago figures, and applied under the most unfavorable conditions. The dilution even under such conditions is about twice as great as that which the Chicago sewage gets, and, therefore, it is, I feel sure, a safe proposition, and I cannot conceive that when, in addition, the distribution is horizontal and 40 ft. below the surface, the sewage could ever be seen.

The reason which seems to have very properly stirred up the population of our metropolis on the matter of sewage disposal in the harbor of New York is the fact that from almost every sewer discharging at the shore line, one sees a long streak of floating sewage matter passing out into the stream and at a number of places along the shores of the metropolis there are massed foul deposits grossly polluting the near waters, particularly when in a slip, bay or other recess. But these conditions are all of easy remedy, when, as in the case of New York, we are satisfied that the liquids can be oxidized by dilution. There are scores of such cases in the large cities of the world.

The floating matter should be held back at the shore, for which there are numerous efficient devices; the liquids should be discharged and dispersed into a sufficient current of deep water, either at the shore or wherever it can most economically be reached, and the depositing matter may either be held back at the shore or more cheaply dredged wherever it may tend to accumulate. Fresh city sewage dispersed into water containing a sufficient amount of oxygen can never putrefy or smell, because odorous gases cannot form. Sludge, if deposited in quantity on the bed of the bay, where the velocity of flow is slight, will putrefy. Therefore, there must either be no areas left available for large sludge deposits or they must be dredged with the necessary frequency to prevent objectionable conditions. Where neither of these conditions is practicable, the sludge must substantially be held back at the shore and defecated, for which there are available to-day efficient and economical means.

EMIL KUICHLING.*—The paper of Col. Black is extremely interesting and gives evidence of a thorough study of the tidal currents in the two rivers and the upper and lower bays. On these intricate features little discussion is possible without a close examination of the numerous observations. The author has, how-

* Consulting Civil Engineer, New York City.

ever, given an opportunity for comment on a matter of the utmost importance by his assertion that the absorption of atmospheric oxygen by the waters of the harbor is so small as to be a negligible factor in the oxidation of the sewage. This statement is contrary to the opinions heretofore expressed in general terms by many naturalists and chemists, and contradicts the results of the recent experimental researches of Messrs. Adeney and Letts, which were made for the Royal Commission on Sewage Disposal and published two years ago in the Fifth Report of that Commission.

In their experiments, Adeney and Letts found that when the water was kept perfectly still and at uniform temperature, the absorption of oxygen by previously de-aerated water seemed to be considerably retarded at the surface, but when the upper portion of the water was agitated to a small depth, such absorption took place much more rapidly and columns of water from 3.6 to 6.5 ft. high became saturated with the atmospheric gases within a few hours. The process of absorption is described as a "downward streaming" of the oxygen without any circulation of the water in the lower portions of the columns of water, as demonstrated by the quiescence of a layer of colored water at the bottom. The cause of the streaming cannot be stated definitely, but it was thought to be due to minute particles of dust, or to centers of condensation of an electrical nature contained in the air, whereby the gas that was absorbed or dissolved in the upper portions of the water would in some way become sufficiently heavy to descend through the column of water by gravity. The authors add that whatever may hereafter be discovered to be the true cause of this streaming, its effect in large volumes of sea or river water under natural conditions must be of great importance and of such dimensions that the effect of ordinary diffusion may be neglected in comparison.

The observed slow rate of absorption of oxygen by perfectly quiescent water in the laboratory cannot fairly be applied to natural bodies of water, "as it is unlikely that conditions so unfavorable to re-aeration exist in nature. Circulation from the surface downward must be set up by thermal currents to some extent in all waters exposed to daily and nightly variations of temperature, even in perfectly calm weather. With such circulating currents the process of re-aeration * * * is probably no quicker than in the experiments with long columns of water whose surfaces were kept continuously broken." These show that the average rates of transmission of oxygen to a depth of 6 ft. in sea water and fresh water are not less than 0.08 and 0.03 cu. cm. per litre per hour respectively, and 0.055 for a mixture of equal parts of sea and fresh water.

A study of the experimental data submitted by Adeney and Letts shows that there is room for much further investigation in this

direction, as the determinations were made only after the lapse of from 12 to 48 hours and more. Other chemists have noted that the re-aeration of water takes place very quickly when it is exposed to the air in thin sheets or is vigorously agitated, and that in some cases a few minutes' exposure suffices for the solution of a large proportion of the quantity of oxygen required for saturation. Some very interesting experiments of this kind have been made by Mr. Geo. C. Whipple, M. Am. Soc. C. E., and it is hoped that they will be described in his discussion. In Dibdin's investigations of the absorption of atmospheric oxygen by quiescent fresh water, it was found that a water absolutely free from dissolved oxygen will absorb from the air in one hour about 10% of the total quantity of oxygen which it can possibly take up after an unlimited exposure at the same temperature and pressure, and about 50% after nine hours; but no figures are given for such absorption by moving water.

In referring to the natural aeration of the water of the Thames above and below London, Dibdin states that as it flows over Teddington weir some miles above the city, it contains 85 per cent. of the quantity of oxygen required for saturation, and is able to deal with all polluting matters contained in it without suffering any material reduction in aeration; or in other words, the rate of absorption of fresh oxygen from the atmosphere is equal to the rate of consumption of dissolved oxygen by the microbes feeding on the organic impurities. Proceeding down stream, it is found that this process abstracts more oxygen from the water than can be supplied at the slow rate of absorption when the water is highly aerated; hence the degree of aeration falls, which is accompanied by a corresponding increase in the rate of absorption from the atmosphere. When the rate is again equal to the necessities of the larger number of organisms feeding on the larger quantity of organic impurities, the balance is re-established and the aeration remains constant at the lower rate. Further down, the organic impurities become less, both by previous oxidation and by dilution, and the quantity of dissolved oxygen in the water gradually increases, until finally at the mouth of the river the degree of aeration is as high as at Teddington weir.

To indicate the enormous quantity of atmospheric oxygen thus absorbed daily by the river, Dibdin computes that when the water is aerated to 80% of saturation, 100 million cu. ft. will take up 8 064 lb. of oxygen in 24 hours, while in the foulest section of the river, between Deptford and Woolwich, where the degree of aeration is only 22.5%, 100 million cu. ft. will take up 98 112 lb. of oxygen daily. At high tide the estimated volume of water in the river between Deptford and Woolwich is 1 099 million cu. ft., and by

making due allowance for the greatly reduced volume at low tide, he estimates that about 538 720 lb. of oxygen are absorbed each day in this section.

Dibdin remarks that "these considerations show the enormous forces at work in purifying our streams and rivers, and which constitute the real secret of Nature's method of effecting the destruction of effete matters, wherever they may be. It must be obvious on the face of it that without some such operation the whole world would soon be covered with rubbish and life would be insupportable. But by these constant processes of interchange, Nature restores the balance, and except where man willfully or ignorantly spoils his surroundings, the world is kept clean and wholesome." Many similar expressions from other recognized authorities in the domain of chemistry and biology might also be cited, but as little is gained from generalities, further quotations will be omitted.

In dealing with the absorption of oxygen from the atmosphere by natural bodies of water of moderate depth, it must be remembered that the water is never perfectly quiescent. Currents are formed both by the wind and by differences of temperature. If the wind is off-shore, the upper stratum of water moves outward more or less rapidly, and is replaced by water from the lower strata; and conversely, when the wind is on-shore, the surface water moves inward and equilibrium is maintained by a corresponding outward motion of the lower strata. These phenomena are made evident to all bathers by the difference in the temperature of the water in the warm season, according as the wind blows off-shore or on-shore, and are further demonstrated by thermometric observations at various depths. Similarly, the action of solar heat produces differences in the weight of a unit of volume of water, and as this action varies with both the altitude of the sun and the shadows cast by passing clouds and the shores, it follows that the equilibrium of the surface stratum is constantly disturbed. Waves are likewise highly efficient means of diffusing the oxygen which is absorbed rapidly at the surface of the water. For all these reasons, it seems unfair to apply to natural waters the rates of reaeration determined from laboratory experiments with still water.

The actual diffusion of dissolved oxygen in natural waters is well illustrated by the results of the determinations of the amount of dissolved oxygen in the water at the surface and at the bottom, at numerous localities in the harbor of New York during the period from June 1 to October 5, 1909, by the Metropolitan Sewerage Commission (Table III, p. 413). In 12 out of 16 cases, the amount of such oxygen was slightly greater at the bottom than at the surface, and in the remaining 4 cases, the difference was very

small. It is of interest to note that even in the case of the highly polluted Passaic River at Newark, N. J., there was somewhat more dissolved oxygen at the bottom than at the surface. An explanation of this condition is offered in the report of the Commission by the statement that the bacteria of decomposition in the surface water probably consumed a proportionately larger amount of its dissolved oxygen.

Similar results have been found by other recent investigations of natural bodies of water, but in opposition thereto are the records of the amount of dissolved oxygen at different depths in Jamaica Pond and Cochituate Lake near Boston, Mass., as determined in the summer of 1891 by Prof. Drown for the Massachusetts State Board of Health. According to these figures, the water was saturated with dissolved oxygen to a depth of 10 feet, but below this level the quantity diminished rapidly until none was found at depths of from 40 to 50 ft. It is probable, however, that this condition did not continue for any considerable period of time, and that very different results would have been obtained after a strong wind. Unfortunately, such investigations have not been sufficiently numerous and thorough to determine all features of the process of natural re-aeration or absorption of atmospheric oxygen by bodies of water.

Associated with this subject are various other observations, such as the frequent super-saturation of natural waters with dissolved oxygen, the evolution of oxygen by chlorophyll-making aquatic plants, the consumption of oxygen by bacteria and other organisms in the water and its muddy bottom, etc. It has been found that under the action of strong sunlight a water containing many microscopic green algæ will absorb within a few hours fully three times as much oxygen as it is capable of taking from the atmosphere alone; and even on cloudy days this action continues, although with reduced intensity. The long-continued investigation of the water of the Rhine at Cologne by Dr. Grosse-Bohle during the years 1902-1904, showed that fresh water does not lose its dissolved oxygen in proportion as the temperature rises. The same author also states that on testing a sample of turbid water which was colored green by algæ and was swarming with innumerable infusoria and larvæ of insects, he found that it contained more than three times as much dissolved oxygen as would occur in pure water of the same temperature; and he adds that many of the large aquatic plants act beneficially, not only by developing oxygen but also by directly absorbing dissolved organic matter. This feature, however, has yet received little attention.

The dissolved oxygen in a polluted water is chiefly available for consumption by bacteria, although some of it is required by the

higher organisms that live in the water or in the mud on the bottom. Adeney and Letts made a number of experiments to ascertain the rate at which the dissolved oxygen is consumed under various conditions by different mixtures of sewage and mud. The results are too numerous for citation, and it must suffice to say that much depends on the quantity of easily oxidizable substances present. As these matters absorb oxygen with great rapidity, they constitute a greater danger to the aeration of the water than the indirectly oxidizable substances. The latter become oxidized through the agency of bacteria, the process being a physiological one, presumably analogous to the respiratory process of higher vegetable systems; and intimately associated therewith is enzymic or hydrolytic action. For the completion of this process more or less time is required, depending on the nature of the substance.

The foregoing brief outline of the remarks of Adeney and Letts on the processes of direct and indirect or bacterial oxidation is not very satisfactory. It may be inferred that direct oxidation is a purely chemical action, and is confined mainly to dissolved organic matter. A portion of the solid matter, however, is also capable of chemical oxidation, and may thereby be rendered soluble in order to be absorbed or assimilated by bacteria. The excretions of these organisms in turn are enzymes or ferments, which have the property of dissolving certain organic solids and thus preparing them either for direct oxidation or for absorption or modification by other organisms. For all these obscure bacterial activities a definite supply of oxygen dissolved in the water seems to be necessary. Another portion of the solid matter is comminuted and swallowed by various protozoa, or higher forms of animal life, which are capable of digesting it or altering its character in some degree; and for this process an additional supply of dissolved oxygen is required. It must not be understood, however, that only bacteria depend for nourishment on dissolved organic matter, as it has been demonstrated that most of the protozoa can thrive in water which contains liquid food alone.

The question now arises as to the proportions of organic matter in polluted water that are absorbed in dissolved form by bacteria and in solid form by protozoa and higher organisms. A definite answer thereto cannot be given at present owing to lack of sufficient data, but from the microscopic examinations of the sediment from such waters, it may be inferred that most of the solid organic matter is attacked and changed in composition by a great variety of animal life. An interesting confirmation of this opinion is given in Prof. Kolkwitz's recent study (in Heft 13, *Mitteilungen aus der Königlichen Prüfungsanstalt,* 1910), of the organisms found in the sprinkling filters of Wilmersdorf, near Berlin, Ger-

many, this plant being the largest of its kind now in continental Europe. In this paper the author mentions 9 varieties embracing 25 species of bacteria, moulds and other plants, and 7 varieties embracing 35 species of protozoa and higher animals, such as worms and insects, as infesting the filters; and he states that these creatures always appeared to be searching for or devouring food. Whoever has watched this performance cannot fail to be impressed with the vastly greater efficiency of such aquatic animals than that of the bacteria and other plant organisms in respect to the elimination of solid organic matter in polluted water.

As already stated, a considerable quantity of dissolved oxygen is necessary for maintaining the activity of these plants and animals, and the only way in which it can be supplied to the water constantly seems to be by absorption from the atmosphere. It cannot be denied that during every year large quantities of organic matter find their way into our streams, ponds, lakes, and seas, and that most of these waters are inoffensive, even when unsuitable for drinking. The most striking instances of such inoffensive pollution are afforded by those portions of our great lakes which receive the sewage of large cities. Here many tons of organic wastes are distributed daily over comparatively small areas of fresh water, and no disagreeable odors of putrefaction ensue. Some kind of purification process is certainly taking place, and our chemists and biologists explain it by stating that it can only be due to the consumption of a sufficient quantity of oxygen to accomplish the oxidation of the putrescible matter. It is therefore somewhat startling to hear that the rate at which polluted water absorbs atmospheric oxygen is so small as to be a negligible factor. Before such a statement can be accepted the most stringent proofs must be given.

In regard to the treatment of the sewage of New York before discharge into the harbor, much might be said, but as definite plans have not yet been submitted, the discussion of the subject at the present time seems somewhat premature. The approved practice for tidal rivers at London and Glasgow is to subject the sewage to sedimentation in large tanks, and let the effluent discharge into the river. In Germany, the cities located on the shores of large rivers are allowed to merely remove the heavy grit and coarse suspended matter by means of brief subsidence in relatively small tanks and the passage of the sewage through screens of from $\frac{1}{8}$ to $\frac{3}{8}$-in. mesh. No offensive pollution of the rivers has yet occurred where this method was adopted, the most notable case being the Elbe which receives at Hamburg the screened sewage from a population of nearly one million.

The main difficulty encountered in the artificial purification of

sewage is the disposal of the solid organic matters which are usually collected in large settling tanks. These solids are always associated with great quantities of water whose removal involves much trouble and expense. At London and Manchester the watery deposit or sludge is pumped into large tank-steamships which discharge the foul liquid into the sea at a distance of several miles from land. In other cities the sludge is pumped upon large areas of ploughed land and then incorporated with the soil, or it is strained through filter-presses and consolidated into masses capable of convenient transportation to other localities. At Providence, R. I., no demand has developed for the agricultural utilization of such sludge-cake, and the material is now being dumped from scows into deep places in Narragansett Bay. With all of these methods of treatment, however, more or less nuisance is associated, either as offensive odors, or as swarms of flies and other insects, so that it becomes expedient to locate the works at some distance from dwellings.

The topographical features of the City of New York are such as to involve many different points of discharge for the sewage; and if it is found on further investigation that a portion or all of the sewage should be partially purified, in order to conserve the salubrity of the harbor, the undertaking will necessarily become very expensive. The eminent engineers who are now studying the subject for the City and State have a great task before them, and their future reports will surely be of profound interest to the profession.

ALLEN HAZEN.*—Colonel Black has presented a very excellent paper. It puts in concise and authoritative shape some things that we have known or felt for a long time, and he has also suggested some new ideas that should prove valuable.

I have had the feeling for a long time that New York Harbor has a most wonderful ability to absorb and dispose of sewage, and that this property is one of the most valuable of the natural assets of the city. It is an asset that is worth hundreds of millions of dollars as compared with other conditions that might have existed here. It is well worth our while to study this asset and see how it can be used to the best advantage.

The fact that fresh sea water is the principal element in the absorption and dispersion of the sewage is fully recognized by Colonel Black, and this recognition marks a great step in advance from some of the ideas that were held a few years ago.

One of the most surprising things in the paper is the percentage of dissolved oxygen which Colonel Black uses as permissible. He states:

"When the quantity left in the water falls below 70% of the saturation value, major fish life begins to disappear; when below

* Consulting Engineer, New York City.

50% the condition of the water begins to be harmful to human health. This condition is evidenced in increasing measure as the remaining dissolved oxygen is reduced, by the discoloration, offensive to the eye, and by the formation of gases, offensive to the smell, and destructive to the paint of vessels navigating therein."

I will not speak as to the disappearance of fish life, but I have certainly had no reason to believe that conditions harmful to human life occurred, or that the other conditions mentioned appeared, while there was any dissolved oxygen left. The relation between human health and local nuisance, if any, is remote.

The other conditions described, are those which I have usually associated with putrefaction and the entire absence of oxygen.

This was tested out in various ways more than twenty years ago at the Lawrence Experiment Station, among others, by artifically pumping air through a filter which corresponded approximately with the sprinkling filters of to-day, and this was done, I may say, some time before Colonel Waring took out his patent upon this procedure.

The filter provided with an air pump operated with an enormous excess of oxygen, but was able to do no more than the same filter when operated in the ordinary way without the pump, so long as some small amount of oxygen remained throughout the filter; and the oxidation of organic matter went forward just as well with very little oxygen as with a large excess.

Much of the oxidation, in fact, still continued to go on for a time after all the oxygen was exhausted. This was possible by reason of the oxygen stored in the nitrates. The nitrates resulted from the oxidation of the nitrogenous matters where there was an excess of oxygen, and the oxygen held in them was again given up to carbon compounds after the free oxygen was exhausted; so that a part of the oxidation and purification process went on freely for a limited time after all of the free oxygen was exhausted.

This was my first experience with the oxygen question, and although it related to conditions somewhat different from those existing in New York Harbor, the lessons learned were clear, and I believe applicable beyond the conditions of the experimental filters.

Afterwards, in London, as the guest of Mr. Dibdin, I went with him, on the laboratory boat fitted for that purpose, through the Thames from the Parliament Buildings to the sewage disposal works at Barking and Crossness and below, and he told me of all the methods that he was using to keep the river and harbor sweet. This laboratory boat was fitted with appliances for taking samples and determining dissolved oxygen rapidly, so that as we went forward the proportion of dissolved oxygen was announced

from time to time. And Mr. Dibdin told me that it was his ambition to so operate the disposal works as to keep some dissolved oxygen in the harbor water at all times, because objectionable conditions first made their appearance when all of the dissolved oxygen was gone, and that he did not believe in carrying the chemical treatment of the sewage beyond that point which would secure the presence of some dissolved oxygen at all points. In other words, when the dissolved oxygen got low, chemical treatment was reinforced in one way or another so as to increase its efficiency, and when more oxygen was present some of the special treatments were stopped to save the unnecessary expense involved in carrying them out.

Some years later, Mr. Dibdin, writing his book, "Purification of Sewage and Water," referred to the condition of the Thames at London, and spoke of the great improvements that had been reached, which had effectively put a stop to the former distressing condition of the river, although the dissolved oxygen at high water fell to as low as 10% at London Bridge, but he notes that this condition does not permit of fish life. He states further that a prolonged series of observations, extending over nearly a quarter of a century, has shown that when the percentage of aeration, indicated by the dissolved oxygen, falls below fifty, there is very little chance of fish thriving in the water, and that when it falls below thirty, it is certain that no fish can sustain life for any prolonged period, and he raises the question whether it may not be worth while to further purify the sewage by the adoption of the "coke breeze bed" system, with which he has experimented, so as to permit the existence of fish life.

The rule then first given me by Dibdin nearly twenty years ago seemed a good one. I have watched it since, and it has been my observation that objectionable conditions in streams where they extend to the whole body of water are practically confined to places where dissolved oxygen is absent. It should be noted, however, that deposits of sewage mud sometimes form about the mouths of sewers, which putrefy out of contact with the air, and the gases so formed come up through the water above and objectionable conditions may result, even where there is dissolved oxygen in the water above the deposits. This, of course, happens only in still water.

I have had occasion to observe, especially during the past year, a river receiving the sewage of a population of, let us say, half a million people. The water has been very low this summer, and the dissolved oxygen in the river below the city has gone down to a point considerably below Colonel Black's limit. Nevertheless there has been no nuisance developed except from deposits of

sewage mud immediately at the outlets of a few large sewers in slack water.

The point of minimum oxygen in this case has been four or five miles down stream from the point where the greatest amount of sewage enters, and only a few miles farther down the water is almost saturated again. I am sure that the surface water takes up oxygen from the air in this case, and in many other cases, to an important extent. I shall be interested to know what Professor Phelps has learned upon this point; but my general experience leads me to believe that oxygen dissolved from the air by water surfaces is often an important element in sewage disposal problems. Of course, the amount absorbed must necessarily be variable. It will be greater when the wind blows, and it will probably also be greater where the currents in the stream are such as to constantly break up and mix the water so that the water from below with lower oxygen constantly takes the place at the surface of water that has been exposed and aerated.

EARLE B. PHELPS.*—The question of absorption of oxygen from the air by water which has had its oxygen content lowered by the addition of polluting material, is one of fundamental importance in any discussion of stream pollution and perhaps I may be permitted a few words upon this subject. In the first place, we must distinguish very sharply between conditions in quiescent water and those in a running stream. The gentlemen who have spoken upon this subject this evening have confined their remarks entirely to the latter phase of the subject, while Colonel Black's statements refer to conditions which very nearly approach the former phase. Our investigations have enabled us with some approximate degree of accuracy to determine the actual state of affairs under all conditions, but we have confined our major work to those conditions which are actually existent in New York Harbor and its tributary waters. Briefly the process of absorption is this:

Given a body of water deficient in oxygen and uniformly mixed, the surface layer begins to absorb oxygen from the air. The initial rate of absorption is determined by the relation existing between the oxygen content of the water and the maximum possible content or saturation value. That is, the more nearly saturated the water becomes the slower the rate of absorption. This principle is almost self-evident and is a fundamental one in physico-chemistry. Obviously if this were the only action taking place the surface layer would soon become saturated and absorption would cease. A second physical principle now comes into play, which is the principle of hydro-diffusion. Under the physical force which is generated by

* Consulting Sanitary Engineer, New York City.

the difference in concentration in adjacent layers, a dissolved substance tends to diffuse from a higher to a lower concentration and at the rate which has been shown to be proportional to the concentration gradient. This is known as Fick's law. Therefore simultaneously with the absorption on the surface there is this diffusion into the lower layers and it is apparent that the total rate of absorption at any time is primarily a function of the rate of diffusion. After any given time the concentration curve plotted against the depth will be nearly at the saturation value at the surface and will decrease in logarithmic form to the initial value at some distance below. This curve measures the concentration gradients at all points and its form determines the rate of absorption at any time. We have studied the mathematical form of this curve and determined experimentally the constants which are involved. From this data we are able to determine the rate of absorption under any combination of conditions of the three variables, depth, time, and initial concentration. The work thus far relates to quiescent conditions.

In any body of water we cannot consider conditions to be absolutely quiescent. The action of the wind, of passing boats, and, what is of much greater importance, the vertical currents produced by tidal movements, all produce conditions which depart from these ideal conditions that we have considered thus far. Coming back to our original assumption once more, it will be remembered that we started with the condition of uniform mixing and proceeded to determine the decreasing rate of absorption with increasing time. The effect of mixing is to bring us back to the initial condition once more and in that way to start the absorption at a new and higher rate. Therefore it only remains to be determined how far our body of water departs from the quiescent state or, quantitatively, about how often on the average it is mixed vertically through any given depth in order to supply the proper time function in our equation and arrive at the actual average rate of absorption in the body of water under consideration. This process involves most detailed study of actual conditions and the actual determination of this average time of mixing will be only roughly approximate. By allowing a generous time factor we shall be able to determine the maximum rate of absorption and shall be sure that the actual conditions are somewhere between this and the minimum rate for quiet water. This has been our method of procedure and this is the basis for Colonel Black's statement that we have found very little material advantage in this reabsorption of air from the atmosphere.

Returning once more to the condition in streams upon which so much stress has been laid, it is readily seen now how we can approximate those conditions in our calculations. Even a fairly

sluggish stream is subject to overturning and vertical mixing at least several times an hour, and this fact coupled with the shallow depths to be dealt with will show, through the application of our formula for aeration, values which are amply sufficient to explain the phenomena of self-purification of streams which have been brought out here this evening.

The serious discrepancy existing between our final results and those obtained by Prof. Adeney in the matter of the increased rate of absorption in salt water over fresh, we have been able to show conclusively are due to experimental errors which we have pointed out and eliminated. The real facts in the case are that the absorption by salt water is very much less than by fresh.

I wish to go on record also as being fully in accord with Colonel Black in the matter of permissible reduction of the dissolved oxygen. I confess to a great surprise at the sentiments that have been expressed here this evening and am confident that they will not bear experimental scrutiny. In my own experience I have time and again seen waters ranging from 25 to 40 or 50% of saturation which were positively offensive to the sense of smell. It must also be remembered that Colonel Black refers to average conditions and any standard for such average conditions must necessarily be safely above the minimum permissible value. I believe that no mistake will be made in establishing the standards that he has suggested.

A. PRESCOTT FOLWELL.*—Like one of the previous speakers, I came here to learn and am sorry to say that I have been disappointed in not learning as much as I had hoped to from Colonel Black's paper on one or two points. I have heard some rumors about these experiments on oxidation and I notice that Colonel Black in his paper spoke very briefly concerning them.

It seems to me, as one or two other of the gentlemen have said, that the greatest trouble in New York, as elsewhere, is with the disposal of sludge. Twenty years ago we did not realize this so plainly, but believed that sewage could be disposed of successfully on sand filter beds; but at that time only small cities were endeavoring to treat their sewage. I do not understand whether Colonel Black meant to imply that it was his aim to solve the sludge problem by the oxidation being tested in these experiments, or merely to increase the purification of the liquid matter; but it seems to me that, as several of the speakers have said, the harbor of New York is ample for the liquid effluent if we can only keep the sludge out of it. I hope that Mr. Hering's conclusions from the two years' experience in Germany with the Imhoff tanks are correct, and that these will do all which they appear to promise to

* Editor, *Municipal Journal and Engineer.*

do, and will play an important part in disposing of New York's sludge.

One of the speakers has stated that New York has a most valuable asset in its large harbor, which furnishes such excellent means of disposing of its liquid sewage. It suggests itself to me that it similarly has a valuable asset in the abundance of low, swampy and over-flowed lands in its vicinity, which can be utilized for the final disposal of inoffensive sludge. Our neighbors in New Jersey have a great expanse of comparatively useless salt meadow land, and perhaps, if they could examine a few loads of Imhoff sludge and find it as unobjectionable as Mr. Hering says, they would allow New York to dump this on the Newark meadows, since this would help them to build the city of docks and factories which they have already planned for on these meadows and are now constructing. Then we have certain members here who are interested in the proposed harbor of Jamaica Bay, which harbor at present consists largely of mud banks, shallow channels and scattered islands too small and too low for any use. There are a great many square miles of area here which could be filled up to advantage with such sludge.

GEORGE C. WHIPPLE* (by letter).—The writer regrets very much that he was not able to accept the kind invitation of President Tuttle to be present and take part in the discussion of Colonel Black's paper, and he appreciates the opportunity that has been afforded him of reading the manuscript. The paper is one of great interest to sanitary engineers and especially to New York engineers who are more or less familiar with the subject. That the paper has been thoughtfully prepared everyone must admit. It is of especial interest, because it takes up the subject of harbor pollution from a somewhat different standpoint from that from which it has been usually discussed. Colonel Black apparently recognizes the hopelessness of the task of keeping the harbor water bacterially pure and has left sanitary matters very largely out of the discussion. Nor does he foresee grave danger from the deposit of sediment in the bay. He is concerned chiefly with the possibilty of the volume of sewage increasing to such an extent that the dissolved oxygen will be reduced to a point where it will cause trouble, and his outlines of proposed methods of purifying the sewage relate chiefly to the prevention of this depletion of the dissolved oxygen.

This brings up the question of what is a safe limit for the depletion of oxygen in harbor water. Colonel Black does not pretend to answer this definitely, but intimates that if the existence of fish life is taken as a standard it should not exceed 30%, and if putrescibility is considered the depletion ought not to ex-

* Consulting Engineer, New York City.

ceed 50%. Regarding the effect of oxygen depletion on fish life the writer made inquiry into the subject a few years ago in connection with the sudden death of thousands of fish in one of the park lakes in Newark, N. J., and at that time learned that it was the belief among scientists that except for especially sensitive fish a depletion of oxygen less than 50% is not necessarily serious. Below this, however, fish begin to suffer and when only 20% or 30% of oxygen is present the mortality is high. Goldfish are said to have lived indefinitely in a sewage effluent containing only 38% of oxygen. Eels will live with still less, but trout require more. This question is one that might be taken up with advantage by the U. S. Fish Commission or by the State Department of Fish and Game and studied on a large and practical scale.

As to a reduction of 50% in the dissolved oxygen being the cause of notable putrescibility, this is contrary to the experience of the writer. He has at times observed unpleasant odors arising from a body of water where the oxygen was reduced to about 20% of that required for saturation, but in these cases the odors were apparently due in part, and perhaps chiefly, to the putrefaction of sludge deposits on the bottom of the river. It is not at all uncommon in polluted streams to see bubbles of gas arising through water which contains oxygen in considerable quantities. In a number of cases also the writer has seen bodies of water in which the oxygen was practically exhausted, yet which gave no noticeable smell. The question of nuisance is one that involves other factors than oxygen alone. It involves the decomposition of sewage sludge on the bottom. Not only may the odors of the discharged gases be disagreeable but the very appearance of bubbles rising through the water suggests decay and is the subject of unfavorable comment by observers. This is one reason why the conditions are so offensive in some of the slips around New York where sewage is discharged and lies stagnant before being mixed with the main current, thus depositing sludge that putrefies.

The plan of Colonel Black to improve the method of distributing the sewage at the outfalls is a step in the right direction. The writer believes that if this problem can be satisfactorily solved the method of dilution can be used by the City of New York with generally satisfactory results for many years to come. To discharge sewage into the quiet water of the slips when there are strong currents of oxygen-laden water passing by in midstream is a waste of natural resources.

In connection with the study of oxygen in harbor water, it is necessary to know how its solubility varies at different temperatures and with different amounts of chlorine. The writer has recently reviewed the literature of this subject and has made some careful experiments at the Polytechnic Institute of Brooklyn, assisted by

Melville C. Whipple, chemist. As a result of these experiments and of the recent work done in England by Charles J. J. Fox, a table has been prepared showing the quantity of dissolved oxygen in saturated waters containing different amounts of chlorine. For the convenience of those interested this table is presented here in abbreviated form.

SOLUBILITY OF OXYGEN AT DIFFERENT TEMPERATURES IN WATER CONTAINING DIFFERENT AMOUNTS OF CHLORINE.

Temperature, C.	DISSOLVED OXYGEN, IN MILLIGRAMS PER LITRE. (PARTS PER MILLION.)					
	Distilled Water (Committee on Standard Methods of Water Analysis).	Chlorine, 0.	Chlorine, 5 000.	Chlorine, 10 000.	Chlorine, 15 000.	Chlorine, 20 000.
0°	14.70	14.62	13.79	12.97	12.14	11.32
5°	12.80	12.80	12.09	11.39	10.70	10.01
10°	11.31	11.33	10.73	10.13	9.55	8.96
15°	10.14	10.15	9.65	9.14	8.63	8.14
20°	9.19	9.17	8.73	8.30	7.86	7.42
25°	8.35	8.38	7.96	7.56	7.15	6.74
30°	7.60	7.63	7.25	6.86	6.49	6.13

Colonel Black has assumed that the absorption of oxygen from the air through the surface of still water is too small to be considered. This statement is a somewhat surprising one in view of the almost constant circulation of the water that is taking place in the upper strata brought about by the wind and by differences in temperature even when there is no wind blowing. In fact the mere solution of gases in water changes its density. It is true that stagnation of water may occur near the surface in times of calm but it does not persist for more than a few hours at a time, so that as a matter of fact new water is being constantly brought in contact with the air. Some years ago the writer made a series of experiments on the absorption of oxygen by water which had been boiled until free of oxygen. In these experiments the boiled water was exposed to the atmosphere in shallow trays and in large jars of different depths. Determinations of dissolved oxygen were made hour by hour and continued until the water was practically saturated. In these experiments it was found that the amount of oxygen taken up by the water, expressed in terms of milligrams per square centimeter of exposed surface, varied greatly according to the conditions of exposure. While the water exposed in shallow trays became saturated before the others it was observed that the amount of oxygen taken up per unit of exposed surface increased rapidly with the depth. If this increase continues to take place, as it doubtless does, when the depth is increased beyond that used in experiments, the absorption must be far more rapid in nature

than in the laboratory and any results obtained by small laboratory tests would be of little value in showing what takes place under actual conditions. The fact that the absorption of oxygen is greater in nature than in small jars in the laboratory is proved by actual tests made in rivers, where after an almost complete exhaustion of oxygen the water becomes resaturated within a comparatively short space of time and with no other source of oxygen than the atmosphere. For purposes of calculation Colonel Black is undoubtedly right in ignoring this factor at the present time, because it is one about which too little is known to enable one to make any definite estimates. Nevertheless, in the opinion of the writer it is an important factor in the problem and in the final analysis ought surely to be considered.

It would too greatly extend this discussion to include the detailed results of the experiments referred to, but by way of illustration the following table has been compiled to show the amount of oxygen absorbed by water when exposed to the air in a shallow pan, a jar, a tall cylinder, after different periods of time. In the case of the samples taken for analysis from the shallow pan the water was withdrawn from a point immediately below the surface, but in the case of the jar and cylinder two portions were removed at different depths. With the tall cylinder one sample was taken from a depth of 6 in. and the other from a depth of 12 in. The samples taken from the different depths showed smaller differences than was expected. For example, on one occasion a sample collected from a cylinder at a depth of 6 in. was found to be 51.4% saturated and at a depth of 12 in., 48.2%. It was seldom that the results differed by more than 10% of saturation in any case.

TABLE SHOWING THE AMOUNTS OF OXYGEN ABSORBED BY WATER WHERE EXPOSED TO THE AIR IN A SHALLOW PAN, A JAR, AND A TALL CYLINDER.

Polytechnic Institute of Brooklyn.

March 28, 1907.

Time of Exposure, in hours.	Temperature, Centigrade.	Area of Water Surface, in square centimetres.	Depth, in centimeters.	Volume of Water, in cubic centimeters.	Dissolved Oxygen.	
					Parts per million.	Per cent. of Saturation.
			Shallow Pan.			
0	20.5	1 435	2.6	3 690	0.07	0.8
0.5	20.5	1 435	2.6	3 690	0.32	3.5
1.0	20.5	1 435	2.4	3 350	0.62	6.7
2.0	21.0	1 415	2.1	2 910	1.05	11.5
4.0	21.5	1 390	1.7	2 330	2.80	30.6
7.0	20.5	1 375	1.4	1 940	4.30	47.3
24.0	18.0	1 355	1.0	1 355	5.80	60.0

Time of Exposure, in hours.	Temperature, Centigrade.	Area of Water Surface, in square centimeters.	Depth, in centimeters.	Volume of Water, in cubic centimeters.	Dissolved Oxygen.	
					Parts per million.	Per cent. of Saturation.
Jar.						
0	22.0	376	20.7	7 800	1.5	16.5
0.5	22.0	376	20.7	7 800	1.7	19.0
1.0	22.0	376	19.7	7 400	1.9	21.6
2.0	22.0	376	18.8	7 075	2.2	24.8
4.0	22.0	376	17.1	6 430	3.3	37.4
21.0	23.0	376	15.5	5 840	5.9	65.8
28.0	23.0	376	13.9	5 230	6.6	75.5
49.0	22.0	376	12.3	4 630	8.1	91.0
Cylinder.						
0	21.5	51.7	78.6	4 060	0.25	2.7
2	22.0	51.7	78.6	4 060	0.57	6.4
7	21.0	51.7	61.0	3 150	0.83	9.0
24	18.0	51.7	42.0	2 170	2.80	28.6

For comparison calculations have been made from the above figures showing the absorption of oxygen in parts per million and in milligrams per square centimeter of exposed water surface for equal periods of time.

Time of Exposure, in hours.	Original Depth of Water (inches).	Increase in Amount of Oxygen Dissolved.	
		Parts per million.	Milligrams per square centimeter.
Shallow Pan.			
2	1	0.98	0.0007
7	1	4.23	0.0061
24	1	5.73	0.0043
Jar.			
2	8	0.70	0.0130
7	8	3.06*	0.0440*
24	8	4.70*	0.0690*
Cylinder.			
2	31	0.82	0.025
7	31	0.57	0.086
24	31	2.55	0.106

* Interpolated.

When water is exposed to the air in drops it absorbs oxygen with great rapidity. In connection with the experiments above referred to the writer made many tests to determine the rate of

absorption of oxygen by drops and thin films of water when exposed to the air for different periods of time. One way in which this was done was to allow the deoxygenated water to fall through the air in drops for different distances from 1 to 64 feet, catching the water after it had fallen for different periods of time from one-quarter of a second to two seconds and determining the amount of dissolved oxygen present. In general the results showed that a water devoid of oxygen will in one second's exposure in drops take up oxygen to the extent of about three-quarters of its possible content, while after two seconds' exposure it will take up from 80% to 90% of the amount required to saturate it at the given temperature. The absorption of the oxygen depends more upon the time of exposure than upon the distance through which the drops fall. The temperature factor was not investigated over a wide range, but so far as the experiments went they indicated that warm water is somewhat easier to aerate than cold water.

EDWIN J. FORT, M. M. E. N. Y. (by letter).—Statements made in this paper in relation to some of the general principles governing modern processes of sewage purification have been quite freely discussed, and this discussion will no doubt be carried to greater length when the paper is published. There are, however, a few points which will bear discussion which have not been mentioned.

The author spoke of the experiments which have recently been carried out at the 26th Ward Purification Works in the Borough of Brooklyn relating to the purification of sewage in sedimentation tanks by the injection of compressed air through perforated pipes laid in the bottom of the tanks, the air bubbles being allowed to rise through the water and escape at the surface.

I understand this to be an effort to supply sufficient dissolved oxygen to reduce the organic matter in solution to a point where the effluent is fit for discharge into tidal water without danger of nuisance, the idea being that such a method of treatment is particularly adapted to conditions in the Boroughs of Kings and Queens. Aeration, which is accomplished by the sprinkling filter by spraying the sewage into the air, is in this case attempted by pumping air into the sewage. A high degree of purification is apparently not attempted, and under the conditions found along the south shore of Kings County, and which can reasonably be expected to obtain within the next 30 years, is not in all cases necessary. Any new method, however, which is brought forward as capable of producing the required degree of purification must bear comparison with older and well-established methods of accomplishing the same results. It must be capable of successful operation by the class of talent that the average municipality

places in control of such works. It must be economical in construction and operation, and the nuisance which is created must be sufficiently less than the one which is abated to make the expenditure worth while.

The cost of the partial purification obtained is not mentioned, but from observation of the experiments and rough calculation of the results, it would seem to be not far from $6.50 per million gallons of sewage treated. By other well-known methods a comparatively high degree of purification can be obtained at a cost of $9 per million gallons.

Test tube or laboratory experiments are by no means conclusive. The practical difficulties of construction and operation on a large scale may offset or overbalance any seeming advantage which they may show.

The City of New York could hardly be expected to commit itself to large expense in adopting a new and untried process upon the strength of a single experiment or even a set of experiments, no matter how carefully they may have been carried out. Before these experiments should be given any weight in the design of purification plants, they should be carried to much greater length and upon a much larger scale.

This proposed method of treatment is by no means a new one. It has been largely forestalled by a similar process devised by Mr. Cecil C. E. Beddoes, of Wallingford, Pa., who took out letters patent No. 895 229 on his process on August 4th, 1908. The device by which this process is carried out, as described by him,

"is an adaptation of a plan for compressing air for blast furnace "purposes, which has been employed for many generations and is "generally referred to as the Trompe Hydraulic Air Compressor. "It has more recently been applied for operating large compressed "air power plants, and high efficiencies have been obtained, but it "has never before been utilized for oxygen dissolving purposes. A "deep shaft is sunk, into which is placed two tubes. The entrance "to the inner tube is at a higher elevation than the outlet from "the large one. Water passes down this inner tube drawing in "with it large volumes of air through induction pipes suitably "placed at the inlet. This air is diminished in volume and in-"creased in pressure in accordance with the depth of water in the "tube above it. The mixture of water and air in equal lengths of "the inner and outer tubes is in balance. A head of but a few "feet is therefore sufficient for compressing the air to the desired "pressure, provided only that the tubes are sunk to the requisite "depth. For compressed air power purposes the liberation of as "much as possible of high pressure air is desired, and it is with-"drawn from the lower end of the downward tube. A considerable "quantity, however, is lost, because it is dissolved by the water. "By the Beddoes process, not only the law under which water at "high pressure will dissolve increased quantities of air is made

"use of, but in addition the surplus pressure air is reintroduced "into the downward and upward tubes, so that none of it is lost "in transit through the device, but instead is intimately mixed "with the water in the finest particles, thereby insuring an abun-"dance of oxygen for assisting bacteriological purification."

As the sewage passes through the siphon more and more oxygen is taken into solution as the pressure increases, until the bottom is reached. As it passes upward on the other side, much of the gas in solution is released as the pressure decreases, and the sewage emerges in a foaming condition. It is claimed that the effluent is completely saturated with oxygen, and that it is possible to obtain a considerable degree of supersaturation. No power is required to compress this air and the first cost of installation of air compressors and a continuing charge for operating them is avoided. A loss of head, however, sufficient to operate the siphon must be incurred.

The author states that the economy of the process experimented with at the 26th Ward Works increased with the depth of the tank as far as a depth of 24 ft., the limit attained in the experiment. This we should naturally expect to be the case, inasmuch as with an intimate mixture of air and water the amount of oxygen absorbed would vary directly with pressure, and inasmuch as the cost of compressing air does not vary in exactly that ratio. In the Beddoes process it is possible to make the siphon almost any depth and obtain any desired pressure without the application of power. The mixture of air and sewage is also much more intimate. It seems as if it should be possible, therefore, to obtain better results at a smaller cost by this device than by that used in the experiments at the Twenty-sixth Ward Works. It is possible too that Mr. Beddoes' patent is broad enough to cover the process which Colonel Black proposes.

Unfortunately Mr. Beddoes died before the utility of his work was fully demonstrated, and in other hands it has perhaps not received all the attention which it no doubt merits. I understand, however, that some progress is being made in perfecting the apparatus, and that the results of experimental work, which has recently been under way, may be soon published.

The experiment demonstrating the possibility of limited dilution of sewage before discharge by the introduction of an enlarged outlet chamber depressed to some depth below the surface of the water into which discharge takes place, was very interesting. It seems to me, however, that in practical operation such a method of discharge of untreated sewage, at least in the waters of New York harbor, would be open to very serious objection, and it is doubtful whether such outlets could be operated successfully for any length of time. The device exhibited proposes to do exactly

what sanitary engineers endeavor to avoid doing at any reasonable cost. The velocity of the stream of sewage is checked in the outlet, so that suspended matter would be precipitated upon the bottom and the cross-section of the chamber diminished until a velocity sufficient to prevent deposit was produced. It would be almost impossible to keep such an outlet clean, and the chances are very great that it never would be cleaned. The velocity of the current at the bottom of the stream is much smaller than that at a higher elevation. In consequence, dispersion would be less perfect, and the tendency to deposit in the immediate neighborhood of the outlet would be greatly increased. The cost of the necessary dredging would be proportionately increased. Moreover, such outlets would be extremely expensive to build.

It is generally conceded that thorough and quick dispersion of sewage is the main object to be sought in locating sewer outlets. If that is correct, then it would seem as if the obvious way to secure the desired result would be to carry the sewage with undiminished velocity directly into a water-way of large volume and strong current.

The statement made that sprinkling filters, because of the unavoidable nuisance from smell, are not adapted for use in the immediate neighborhood of cities, should not be accepted without qualification. There are too many successful sprinkling filter plants in operation in the neighborhood of cities at the present time which do not create an appreciable nuisance to warrant such a sweeping condemnation of them. It is true that the most important sprinkling filter plant in America, the one in Columbus, Ohio, has been referred to a number of times as an example of what may be expected in the way of nuisance under all circumstances wherever a sprinkling filter is built. It seems to be conceded that this plant undoubtedly creates a strong odor in its immediate vicinity, but it should be remembered that it is located at some distance from a populous district, and it is a fair question whether under such circumstances any great amount of expense to avoid smell would be warranted. If there is no one living within the range of the smell, then no one is injured by it and no nuisance is created. It deals with septic sewage, whereas it is now generally accepted as a fact that better results can be obtained under such circumstances with fresh sewage. The sewage is in a septic state when it reaches the plant. The septic tanks are so designed that little variation in the period of retention is possible. It is not improbable that changes might be made in this plant at reasonable expense which would almost or entirely eliminate the present objectionable odors, and if not, then it does not follow that with a sewage of different composition, which may carry different percentages of trade wastes or mineral salts, such works may not be

so designed and operated as to be practicably without objection in this respect.

At the International Engineering Congress held at St. Louis in 1905, Mr. H. Ross Hooper, M. Inst. C. E., Engineer Inspector of the Local Government Board of England, speaking of nuisances arising from sewage disposal works, said, "These may be said to be practically *nil*, except in the case of insufficient attention on the part of employees, and the fact that many hospitals, asylums, recreation grounds, etc., often adjoin the works, without any bad effects, is sufficient to prove that they are not necessarily dangerous neighbors." Mr. Geo. W. Fuller, in discussing the subject on the same occasion, practically confirmed this statement. The evidence of many others who are most familiar with the results obtained in Europe, is to the same effect.

My own observation of such works, though limited, has led me to the same conclusion. At Salford, the streets immediately bordering the works are built up solidly by residences and buildings used for business purposes. The manager's residence is also located within a few hundred feet of percolating beds. He stated to me that no annoyance was created by odors from the works. The list of English plants operating under similar conditions and with similar results is a long one. As against such evidence as can be offered in regard to a great number of such works the fact that the works at Columbus treating highly septic sewage are odoriferous has little weight as to the possibility of designing sprinkling filter plants which shall be without nuisance. It is well to remember also, so far as the treatment of sewage in the neighborhood of Jamaica Bay is concerned, that the plans adopted for land development in its immediate neighborhood indicate that it will be used for business purposes only and that it will not be used for residence purposes to any extent. What might be objectionable in a high-class residence district, would not necessarily be so in a district occupied by railroad tracks and warehouses.

Where the removal and treatment of suspended matter only is required, the Imhoff tank promises to give most satisfactory results and to be without appreciable odor. In a thorough trial of it made by the City of Philadelphia during the last year, it seemed to justify all the claims made for it and its construction as a part of the permanent purification works for the city has been undertaken. I understand that it has also been recommended for the cities of Batavia and Atlanta.

Should the Beddoes siphon prove to be as effective as is reasonable to expect, a practicable and very economical device will become available for carrying purification a step farther, and, no doubt, to the point where a stable effluent may be produced.

KENNETH ALLEN, M. M. E. N. Y. (by letter).—It is well that the question of dissolved oxygen be given a prominent place in any discussion relating to the disposal of New York's sewage, for it is mainly upon this that we must depend for its final and inoffensive reduction. Its amount depends partly on the volume of inflowing well-aerated water, its temperature, salinity, the relation of exposed surface to depth, and the volume and character of the pollution received.

After the positive statements of Dr. Adeney in the Fifth Report of the Royal Commission on Sewage Disposal regarding the re-aeration of sea water from the surface the conflicting results obtained by Prof. Phelps are of particular interest. In the above report Dr. Adeney mentions a very rapid transmission or "streaming" of oxygen downward after once being absorbed at the surface, which he does not pretend to explain but which is not in the nature of ordinary diffusion. He says, "* * * the re-aeration, of waters in calm weather, when they have become partially or wholly de-aerated by pollution, takes place with extreme slowness," but that after being once absorbed "the downward streaming effect takes place so rapidly, when the surface of the water exposed to the air is continuously agitated, that long columns of water are completely saturated with atmospheric gas with comparative rapidity." "It is * * * evident from these experiments that whatever may subsequently be discovered to be the true cause of streaming, its effect in large volumes of sea or river water under natural conditions must be of great importance and of such dimensions that the effect of ordinary diffusion may in comparison be entirely neglected."

The rate of this transmission of dissolved oxygen when the surface is disturbed, but the weather calm, he finds to be, to a depth of at least 6 ft.:

In sea water..... 0.08 c.c. per liter per hour.
In fresh water ..... 0.03 " " " " "

The rate at which absorption of oxygen takes place at the surface of still water has been stated by W. J. Dibdin* as follows, taking 2 cu. in. per imperial gallon as complete saturation.

In	1	hour	10%	of	the	total	possible	quantity.
"	2	"	20%	"	"	"	"	"
"	3	"	26%	"	"	"	"	"
"	4	"	32%	"	"	"	"	"
"	5	"	36%	"	"	"	"	"
"	6	"	40%	"	"	"	"	"
"	7	"	43%	"	"	"	"	"
"	10	"	50%	"	"	"	"	"

* The Port of London and the Thames Barrage, 1907.

With the surface broken by wind the rate of absorption would of course be increased.

From a series of samples of the Thames Dibdin found a saturation of 80% between Teddington and Chiswick, above London, while at Woolwich it had decreased to 26%, from which point it rose to 90% at the Nore; showing the absorption due to the pollution of the city above Woolwich, while below that point re-aeration exceeded that due to this cause. Between Teddington and Southend he estimates an absorption of 2 384½ tons of oxygen per 24 hours, varying from 3.6 to 43.8 tons per million cu. ft. of water. "These considerations," he says, "show the enormous forces at work in purifying our streams and rivers."

The admissible depletion of dissolved oxygen is a matter on which engineers should reach some agreement within reasonable limits. This is brought home by the fact that while the author of the paper advocated 70% as the limiting degree of saturation, Mr. Hering mentioned 30% as meeting the requirements of the authorities for the Thames at London and Mr. Hazen appeared to sanction the entire withdrawal of oxygen, at least for short periods. The value in dollars and cents of 70% of the total of saturation if released for sewage purification would be enormous, but the writer believes a conservative position should be taken on this question, provided it is reasonable. This would seem a particularly desirable safeguard in so important a harbor as that of New York.

If the limit is to be fixed with regard to the influence on fish life it should be remembered that the effect on different varieties is very different. The findings of the Royal Commission* are perhaps worth mentioning as expressing the opinions of various investigators.

Thudichum kept fish in water from 25 to 30% saturated, but they barely lived. With over 50% saturation they were unharmed.

Noel Paten concluded that less than ⅓ the normal oxygen (2 cc. per litre) is prejudicial to young salmonoids.

Konig said that fish can tolerate without ill effects water containing 2.2 cc. of oxygen per litre or ⅓ the amount usually found in flowing water.

Dibdin stated that dace, gudgeon and minnows finally succumbed with 20 to 25% of saturation. He considered 50% necessary.

Hoppe-Seyler and Duncan said that with from 3 to 4 cc. of oxygen per litre tench kept in good condition for from 13 to 22 hours. With .8 to 1.7 cc. trout were restless after 1½ to 2 hours. With less than 0.7 cc. per litre tench kept alive for from 4 to 20 hours, but were "in a bad way." They concluded that when the

* Report V, Appendix VI, p. 207.

water was half saturated tench would remain practically unaffected for a considerable period; when from ¼ to ⅛ saturated trout were rapidly and seriously affected, and while with a further reduction sluggish fish (such as tench) might exist for some time but probably not long.

The general conclusion of the Royal Commission conforms to that of Konig, viz.: that fish can tolerate water with 2.2 cc. per litre of oxygen, or ⅓ the amount found in flowing water. And they add: "It does not appear that liquid sewage matters, when free from directly poisonous substances, exercise any injurious effect on fish, if present in comparatively small quantities."

In a paper presented to the Society of Arts in 1897 Thudichum summed the matter up as follows:*

"When the rate of absorption (of oxygen) was never below 50% of the total possible aeration fish would exist and thrive; so long as the degree of aeration exceeded 20% of saturation, at which point the rate of re-absorption was enormous, fish could not live, but wholesale putrefaction such as was seen in the Thames in 1884 and 1887 could not take place; when the organic matter was in such excess that it brought the degree of aeration below 20% of the possible, then, although the rate of reabsorption was approaching the infinite, the river could not cope with it."

The above opinions suffice to indicate that if merely to protect fish life a standard of 70% saturation is higher than necessary.

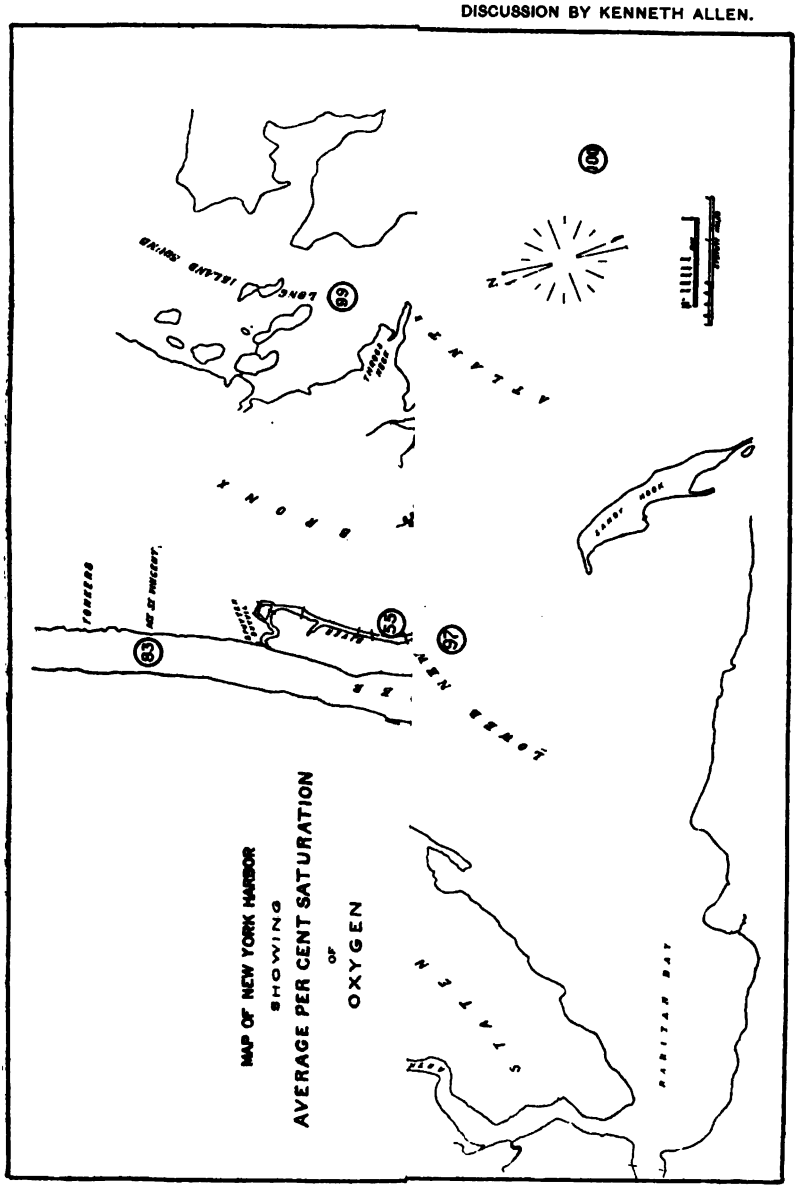
But in any attempt to fix an average degree of depletion as a standard due consideration should be given to the fact that in slips, basins and bays, where pollution is greatest, the dissolved oxygen will be far from the average. For this reason a very low average limit seems to the writer inadmissible as permitting local conditions that would cause offense. Whether fish life is to be preserved should depend on the relative value of the fisheries as compared with the oxygen otherwise available for purposes of purification.

The Rivers Pollution Commission of England, in its report of 1867, claims that fish will not "be killed, as has been ascertained, even by the flow of town sewage, *while it is fresh,* when it does not exceed half the volume of the stream into which it passes, and where the water is in unceasing motion downwards, not tidal as in the Thames at London," while Mr. Hering states as his opinon (*Transactions,* American Public Health Association, Vol. XIII) that "to sustain fish life (rivers) may receive sewage from 1 000 persons for at least every 150 to 200 cu. ft. minimum flow per minute, supposing that natural subsidence of heavier matter takes place immediately below the town discharging the sewage."

In short, it is pretty well understood that *if the supply of oxygen is kept up* the mere presence of large quantities of fresh sewage is

* *Journal*, Society of Arts, Dec., 1897.

PLATE 60.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
BLACK ON SOME PROBLEMS
IN SEWAGE DISPOSAL OF NEW YORK.
DISCUSSION BY KENNETH ALLEN.



not detrimental to most fish. This is sustained by the fact, as stated to the writer several years ago by Mr. W. M. Brown, Chief Engineer, that large quantities of fish are caught by the employees of the Metropolitan Sewerage Works close by the Deer Island outlet in Boston harbor.

Assuming that 50% saturation is a fair figure if fish life is to be preserved the question still remains at what perecentage objectionable conditions may arise. The writer does not feel competent to pass on this difficult question. Much depends upon the duration of the minimum saturation and much on the conception of what constitutes an objectionable condition—a matter upon which individuals differ.

In the work of the Metropolitan Sewerage Commission large numbers of samples of water from various parts of the harbor were examined for dissolved oxygen and the average results (excluding samples from near sources of pollution such as sewer outlets) for each of the main bodies of water are published in their recent report. These show degrees of saturation varying from 55 in the Harlem River to 67 in the Upper Bay and 97 in the Lower Bay. (See Plate 60.)

Referring to the net southerly discharge of the East River, the U. S. Coast and Geodetic Survey, after reviewing the various gagings made by them in the past, revise their earlier estimates and conclude that "it can hardly be said that our observations upon the currents indicate a net discharge in either direction through Hell Gate. They indicate, as a rule, the stream having the larger cross-section has the smaller velocity, and *vice versa,* thus leaving the question of the amount of net discharge uncertain." While no adequate gaging has been made to answer this question positively it is believed that such a discharge toward the Narrows does exist although probably of much less volume than generally supposed.

The results of the experiments of Colonel Black and Professor Phelps on the oxygenation of sewage will be looked forward to with great interest by sanitary engineers as promising a more efficient method of securing this than such methods as those of Lowcock in England and Waring in this country.

The conditions affecting sewage purification works in and near New York are very varied. In Manhattan we have the densest of populations and the highest of land values to be found, while in southern Richmond there are large areas of land but partially cultivated and with sparsely scattered farm houses. On the estuaries and bays of the upper East River and bordering Jamaica Bay may be found many square miles of marsh land seldom visited by man, while midway between, on the backbone of Long Island, are well built-up and rapidly growing communities.

As pointed out by the author, the method of purification best adapted to one locality may be entirely inapplicable to another. For this reason the best plan may involve several entirely different methods. But in any locality, with the possible developments of the future, it will be desirable to occupy as little space as practicable in disposal works and it is earnestly to be hoped that the experiments of Colonel Black will furnish a step in advance in this direction.

GEORGE T. HAMMOND, M. M. E. N. Y. (by letter).—The subject presented by Colonel William M. Black is, it seems to me, about the most important that this Society can easily find for its careful consideration. The problems that he presents are so many-sided that I think we should give it our full attention for at least another meeting, which should be provided for the discussion of Colonel Black's very interesting paper.

Having served this City in an engineering capacity, involving sewerage design and construction, and also in its water supply department, for many years, during all of which I have heard frequent discussions on these problems, some discussions filled with dismal forebodings, and all of them that I recall filled with sincere thought and aim to improve methods, I may almost be permitted to speak as an old inhabitant sometimes talks about the weather.

There can be no doubt that our problems, as they arose, were carefully considered by such men as James P. Kirkwood, Julius W. Adams, William E. Worthen, Alphonse Fteley, all Past-Presidents of the American Society of Civil Engineers, each of whom, at different times, was entrusted with the design of our Brooklyn sewers, or with the solution of problems presented by the sewerage of the old City of Brooklyn, now a portion of the Greater City.

Mr. J. W. Adams, in a report to the old Brooklyn Board of Health in 1876, tells us among other things that "the question is beginning to be raised as to the final result that will grow out of this constant discharge into the slips of the two cities" (*i. e.*, New York City and Brooklyn). "Fresh sewage is lighter than sea water," he tells us "and will be conveyed by the tides to the sea, but the heavier contents of the sewers are being deposited into the slips and on the flats adjoining the shores of the harbor and bay, and the question of its disposal will at some future date force itself upon the attention of the inhabitants as the great problem of the day. * * * Indeed it is probable that years must elapse and folios of reports be written before the matter will be taken up in earnest by our people, so difficult will it be to convince them of the importance of the subject, the encroachments, meanwhile, being so quiet and so gradual; but the shoaling of the harbor from the deposit therein of hundreds of thousands of tons yearly, although

almost imperceptible in its progress, very properly calls for some investigation even at this early day."

He then proceeds to tell us that "there are three methods known by which this evil can be effectually arrested, but that the cost of either of them is so great that it is needless to go into the subject further than to indicate the methods alluded to;" these are:

"*First:* The system of interception which has been carried out in London—cutting off entirely the discharge from the sewers into tide water within the limits of the cities and carrying the material by conduit on both shores to the sea.

"*Second:* By constructing reservoirs at the outfall of the main sewers and pumping the sewage into boats, thence carrying it during ebb-tide at the mouth of the harbor into the sea.

"*Third:* Pumping up the sewage and carrying it, by pipes, to the barren lands on the shore of Long Island,—the process known as irrigation."

Since Colonel Adams wrote the above report "folios of reports have been written" on the subject and yet we seem but little, if any, nearer the solution of the problem. The art of sanitation as a laboratory art has advanced immensely, and we undoubtedly know more about the biological and chemical features of the sewage problem than did our fathers and grandfathers, and yet all of our great rivers are still being polluted, and, is it not true that we are still hearing from out the partly opened laboratory door, a promise of good things to come? Are not the doctors still telling us that they *are just on the eve of a great discovery which will solve our problems?*

So the eve of this great discovery drags on into the night and darkness, and we engineers are, as yet, after more than forty years of promise, still hoping for and trusting in, as indeed we must, this great discovery soon to be announced. I can recall the time, not so very long ago (1895) when I was engaged upon the construction of the Twenty-sixth Ward Sewage Disposal Plant, then the largest and most important project of the kind in America. We all expected it to do the greatest of great things; it was ingeniously designed and carefully built; it had many moving parts, all fearfully and wonderfully made; and it cost about a third of a million dollars. The most famous engineers and chemists of the day were in consultation upon it and it was considered that it was a great improvement on the great plants in England,—and now we must frankly call it a failure and little better than a nuisance. We have, in Brooklyn, four such plants. Then came Colonel Waring with his aerating filter, one of which he built in our borders at Homewood, and which, in spite of all croaking prophets, worked well until it became unnecessary on account of changes in the sewerage system. Since then the septic tank has appeared, heralded by our

most eminent sanitarians, and this, too, has gone its silent way and is heard of no more, except in careful explanations of past promises. The sprinkling filter and the percolating filter have since come, and are still with us, and in view of the excellent record they are making abroad, I cannot agree that they shall be hastily condemned. Last of all comes the Imhoff tank.

The laboratory door is not yet thrown open wide; the chemists do not yet agree, and so we await the next announcement. Colonel Black tells us that we should have 70% of dissolved oxygen in our harbor water, and he hopes to preserve it by blowing air into the sewage in deep tanks, having screens in their bottoms through which the air is discharged, etc., and so we must wait awhile longer for the full light to flash upon us from out of the laboratory door. Meanwhile we must go on as we have gone in the past, designing and building sewers, wasting the peoples' money, perhaps, while we await the fulfilment of the promises of good things to come.

It is rather disheartening to a mere civil engineer to hope for so much and to find so little. Experiments are made, the results are published, the engineer takes the report and "with hope shining on his helm," designs his work, and yet—his work is a failure; *the tank stinks and "the stench carries three-quarters of a mile to a mile and a half,"* as at Columbus, O. He designs a storage tank "to hold back the sewage flow and discharge it on the falling tide, as at Boston; result—bad!" The harbor is becoming polluted in spite of his long outlet mains, his costly reservoirs and his expensive pumps; laboratory conditions and actual conditions are so different. Baltimore, Md., is just now finishing a sprinkling filter plant, in which all of the best features to be gained by a preliminary experimental plant and a close study of the great English sprinkling filter systems are provided at very great cost. Will this succeed? Will its tanks smell any better than those at Columbus, O.?

In view of the evidence collected by various observers in England, I cannot bring myself to believe that the new Baltimore plant will be a failure, or that any better method for a large city has as yet been invented.

The new Imhoff tank seems to promise great results, but it makes no claim to complete treatment. Dr. Imhoff, while on a recent visit, told the writer that he considered that in almost every case no treatment of sewage was necessary further than the removal of the matters in suspension, but about one-tenth of which, he stated, could possibly be removed by means of ordinary screens. He considered that at least one-third of the suspended matters would, in most cases, pass any possible arrangement of screens. The Imhoff tank is planned for the passage of sewage over it in about two hours, but it accomplishes about 80% of its removal of sus-

pended matter in one hour, removing not more than about 85% to 90% in two hours. If, then, the sewage has previously been about two hours in reaching the tank, it will be about four hours old, and rather stale on leaving the Imhoff tanks, but not septic. It would seem that its condition at this point would be such as to invite aeration, and, if this can be accomplished by the methods being studied by Colonel Black and Professor Phelps, perhaps we shall soon be in a position to take a great step in advance.

The aeration of sewage by means of air forced into it, or forced through it, is by no means a new suggestion. Dr. Imhoff informed the writer that this had been tried out to a conclusion in Germany, and that it had not succeeded. It was tried here in America at the Lawrence Experimental Station, and in other places. It was the basis of Waring's aerating filter (which latter I do not think was entirely a failure). An American engineer, Mr. C. C. Beddoes, has secured a patent (No. 895 229), one of the claims of which is for "the process of treating sewage for the purpose of supplying the same with oxygen to support bacteria, which consists in supplying air or gas to the sewage and subjecting the sewage and air or gas to pressure at the same time," etc.

A combination of the methods of Imhoff and Beddoes may perhaps revolutionize sewage treatment. On all theoretical points, such a combination would seem to be ideal, as the Imhoff tank removes the suspended matters, taking the sludge problem out out of the question, and prepares, so to speak, the sewage for aeration. Now the method of Beddoes is the well-known air compressing siphon, by means of which compressed air is secured for industrial uses; air compressed to any desired pressure by flowing water carried down in a pipe, to whatever depth is required to obtain the desired air pressure. The air being taken off sufficiently low down to give the pressure desired, and the water brought back to the surface and discharged at a slightly lower elevation than its entrance point. In passing through such a siphon, all of the flowing sewage is subjected to air under pressure. This method also makes the driving of air compressors unnecessary, as the flowing stream does all of the work itself.

I should much like to see proper experiments made to try out the Imhoff tank in connection, either with Professor Phelps' deep tank or Mr. Beddoes' deep inverted siphon, or indeed with both of these appliances. The tank being at present experimented with by Professor Winslow, which seems to be operated in a manner exactly contrary to the Imhoff, might also be tried out.

If the Imhoff tank can be installed at each sewer outlet along the water front, and the discharge from its deep chamber be removed in scows, this would seem to afford a local means of treating the

sewage, go a long way toward preventing fouling of the harbor, and if the siphon of Beddoes, which requires no mechanical force in operation other than gravitation, or even the tank of Phelps, which requires rather a high cost for installing and operating for air compressors, etc., can be provided at each place in addition to the Imhoff tank, and this proposed outfit will only work successfully, it would seem that the problem of sewage disposal can be solved, in at least so far as the laboratory can solve it; but the practical side is far from easy of solution. The details of design, the difficulties caused by local conditions and local interests, existing sewers, etc., must be considered.

There is a practical side to the sewerage problem, which not only concerns sewage, and the refined chemical and biological studies involved in the laboratory study of sewage disposal, *but also concerns sewers—mean, humble, actual sewers*—which property owners must and will have, whether there be fish in the harbor or not, and property owners care less for the esthetic purity of the harbor or beauty of a clean foreshore at Coney Island than they do for their own houses and streets in the City, and they are citizens, taxpayers and voters. They not only will have sewers, but they will have them at *moderate* cost of construction and maintenance. They may take great interest in keeping the Jersey sewers out of the harbor, but when it comes to *their* sewers, that is quite another matter.

Having paid millions of dollars for sewers, they do not feel like doing it all over again to please us, and they will probably defeat any measure that is going to purify the harbor at the cost of a large general land assessment, especially if there is much room for difference of opinion as to the amount of pollution the harbor can digest without giving rise to a nuisance.

There is another feature of this subject that should also be considered; that is, what part of the pollution comes from house drainage and what part from the storm-water washings of the city?

I beg to call attention once again (for it has often been stated by sanitarians) to the fact that the storm water which discharges from the sewers during the first thirty minutes of a shower is more foul than the ordinary dry weather flow. I will not go into the reasons for this, but will say that my own observations made on the storm sewers of Brooklyn, over a period of ten years, and my study of the existing storm sewers of Baltimore (where I designed the new storm-water system of drains, as Division Engineer of the Storm Water Division under Mr. Hendricks in 1906), lead me to the conclusion that we must treat the storm flow in some manner, or the pollution of rivers will not be prevented by merely treating the dry weather flow only. I think there can be no doubt that the

greater part of the dredging required at sewer outlets in this City is caused by storm flow. The Gowanus Canal is a good instance of a body of water fouled principally from flow of other than house sewage, but little of which can enter the canal, except in the time of storms. There are a great many sources of river pollution besides the dry weather flow of sewage. This problem is closely connected with the street cleaning problem and the snow and slush problems. Many people, and some who should know better, consider that everything of every kind should go into the sewer. Watch a street cleaning gang, and you will see the horse-droppings and filth of the gutter being brushed into the catch-basins, or even into the manholes, and in many places you will hear that it is a good thing to flush off the street surfaces with city water, carrying all of the filth into the catch-basins and so through the sewers into the harbor, for the catch-basin arrests but a small part of the suspended matters that the storm water or flush water carries into them; nearly all of the material goes into the sewers, and if there is current enough, into the harbor at the mouth of the sewer. If there is not current enough to carry such matters onward once, they await a storm, meanwhile partially damming up the sewer and putrefying. Slush and snow are also great offenders, but what can you do to prevent them? You will observe that after snow has remained on one of our streets two or three days the snow water or slush melted out of it, is fouler than ordinary sewage, and carries more sediment and more matter in suspension. This must all pass through the sewer into the harbor. What shall we do with it? I must also call attention to the further fact that the organic impurities to be found in the gutter wash, such as swill, small pieces of meat, vegetable matter and the washings of sewers, street basins, etc., are more resisting to bacterial destruction than is fecal matter in the house flow, and quite as likely to pollute the harbor.

As to the relative quantity of storm flow and dry weather flow, an unfortunate condition exists. While the dry weather flow is subject to fairly well-known and constant daily quantity and variation, the storm flow comes in great deluges and very irregularly.

It would appear that, after all, Nature has a way of doing things on a large scale that our laboratory students scarcely appreciate. The absorption of oxygen by the water in the harbor probably goes on at a higher rate than elsewhere where the pollution is greatest. Dibdin has shown this and there are doubtless many ways by which the absorption of oxygen occurs, which are increased in efficiency by the need of a greater supply. The practical working out of compressed air plants for supplying the quantity of air required for the purification of sewage, the proper location of such

plants and their proper maintenance, are problems of the gravest moment when one attempts to undertake their introduction into such sewerage systems as now exist in Brooklyn and Manhattan. Indeed, after all is done, it may well be that such installations will prove unnecessary. It is quite possible that if we screen the sewage carefully, both storm flow and house flow, and carry the screenings and sludge from the screen tanks to sea in scows, we shall never require any other treatment for the sewage now discharging into the harbor or the rivers adjacent. It is quite certain that screening of the storm water and a treatment of the house flow will be required at all sewer outlets into Jamaica Bay or water-ways of this kind.

I observed with great interest the experiment exhibited by Colonel Black and Professor Phelps, showing the discharge of blue liquid under a considerable relative pressure, by means of a vertical glass tube turned at the lower end into a horizontal tube, placed in a glass water reservoir, filled partly with water so as to show the effect of discharging the colored liquid under pressure into a body of water entirely at rest. The experiment shows that the blue liquid discharged under considerable head at the bottom of the reservoir disseminates slowly through the whole mass of the contained water in the reservoir. It also shows that the blue liquid crawls along the top only of the horizontal discharge pipe at the bottom of the reservoir.

If this experiment is intended to show that the discharge of the blue liquid under a head into still water contained in a glass vessel in a laboratory is anything like the discharging of sewage into a river *not* in a quiescent state, I must beg to ask further light, especially if this experiment is thought to justify submerging the sewer at the bulkhead to the bottom of the river and carrying it thence along the bottom several hundred feet. How far out should such a submerged outlet be taken and of what size relative to the expected flow should it be? If there is a current in the river, how can we prevent it from sweeping the flow at once to the surface of the river, since the sewage is lighter than the salt water? How can we keep the sewage from silting up the submerged pipe through its whole length and when so silted, how can we clean it out? If this discharge is into still water, how can we keep sludge from piling around the outlet as materials do about the mouth of a volcano, for note that the discharge of the submerged pipe is analagous to a continuous erruption, there being velocity at the center only, and suspended matter tending to fall back at once on escaping the velocity of discharge.

If this principle were to be applied to our existing sewers, the result would, I believe in nearly every case, prove a local nuisance.

Recollect that our sewers are all combined and all carry vast quantities of silt in storm times and sludge in dry weather, nearly all of which would be deposited at the immediate vicinity of the submerged outlet. If these submerged outlets were proper in size for storm discharge, they would be entirely too large for dry weather flow and constitute submerged settling tanks, if not septic tanks, between storms. Again, the cost of such structures would be appalling and their maintenance almost impossible. To have such a design of discharge outlets, we should have to rebuild a large portion of our sewerage system, and at least to screen all of the flow before discharge.

I am convinced that wherever it is possible, the storm flow should be discharged directly into the swiftest part of the flowing current of the stream, into which it is led, or at the pier-head line, and that it never should be permitted to discharge at the bulkhead line or under a pier.

Considering the vast volume of storm water which we are often obliged to discharge at one point in most instances, it would be useless to carry it to the bottom of the salt water in the harbor. It would rise at once if you did carry it down. Stop and consider 500 cu. ft. per second and think whether you could expect this to be mingled at once with the salt water which is in an almost static condition at the bottom of the river. We have a number of outlets that carry more than 500 cu. ft. per sec., and the discharge must always be with some velocity, otherwise the cost of sewers will be prohibitive. Dry weather flow, if it must enter the river untreated, should also be discharged at the pier-head, and well into the flowing current of the river. Here there is a chance for securing a more complete dilution before the sewage rises to the surface, and the discharge may be divided through a number of outlets, but the outlets should never be in the bed of the river if there is little or no movement in the mass of river water, otherwise we may well expect that the outlet will silt up and the difficulty of cleaning will be very great.

Relative to dissolved oxygen, there can be no question but that 70% of saturation is a very safe and desirable ratio to maintain, if it can be maintained without involving a cost out of all proportion to the benefit to be derived from so high a ratio. So far as any nuisance is concerned, this ratio will certainly prove safe, but unnecessarily high. Indeed it seems doubtful if it can be maintained unless the storm-water flow is treated as well as the house flow, and in view of the pretty well established facts relative to river pollution elsewhere, it seems as though we will have to be satisfied with a much less ratio.

Several things in Colonel Black's paper, to me at least, are disappointing. He does not give us sufficient information to enable

us to form an opinion as to the success of the aeration experiments in open tanks, made at the Twenty-sixth Ward Sewage Disposal Plant. Judging from the few things that he says about these experiments, they have had but slight success. It is obvious that officials entrusted under the charter with the duties of sewer design and construction must perforce occupy the psychological situation of a certain man, who came from Missouri, and *"have to be shown"* results. Colonel Black's paper, though so excellent and so interesting, leaves us with a painful feeling of the immensity of the subject of City sanitation, and illustrates how difficult it is.

The paper, taken as a whole, is immensely interesting. Our Society should give all possible encouragement to such studies. Let us hope that the problems which are scattered abroad around us may all be tackled in such an admirable manner. Possibly after the accumulation of such studies or the writing of folios of reports, as Adams puts it, the day may come when our people, who foot the expense bills, will seriously take up the question of sewage disposal.

WILLIAM M. BLACK.—The interesting discussion produced by this paper is a proof of its utility. It is evident that there is a lack of agreement as to standards among the men who have studied most extensively the effects of sewage disposal by dilution in New York Harbor. It is further evident that the question of what standard of purity shall be adopted is to a great extent economic. Until a standard be adopted, how is it possible to determine to what extent sewage purification is necessary, and if the degree required be not known, how can economical purification methods be selected?

There is even disagreement as to whether any purification is required to-day. On the one hand, the State and City of New York have entered the Courts to prevent the Passaic Valley sewage from being discharged into the Upper Bay. On the other hand, the State of New York has given permission for the unpurified discharge of sewage from a system, designed to provide for a population of 850,000, at a point in the Hudson River immediately north of the City limits. Mr. Hazen seems to believe that as long as any oxygen is present in the waters, their purity is sufficient for the harbor of a great city. Mr. Hering fixes the oxygen limit at 30% of the saturation value. Mr. Allen gives 55% of the saturation value as the amount of dissolved oxygen found in the Harlem determined from an average of the observations of the Metropolitan Sewerage Commission. The writer has passed through the Harlem at a time when a long reach was so polluted with sewage as to be offensive to the eye and nose.

Is it not a fact that the amount of diminution of oxygen allowable in any waters must be determined from the local conditions? Climate, the use of the waters for navigation, the population along

the banks, the uses to which the shores are devoted—all must be considered. No criterion can be drawn from the possibility of drinking the water after filtration. That treatment is especially designed to restore the water to its original condition of purity, including the restoration of its oxygen. Enthusiasts have been known to drink the effluent from a sewage filter. Nor can the experience of European cities be taken blindly as a reason for adopting methods in New York. It is known that there is a marked difference between the sewage of Europe and that found in the United States and that some purification processes give results there quite different from those secured by the same processes when used on the more dilute sewage here. The question must be studied in New York for New York, and the solution must be suited to the conditions of New York.

The writer has suggested that the presence or absence of higher fish life be taken as a criterion. If the higher forms of fish life can be reintroduced and can exist in the waters of New York Harbor, it would indicate that the general purity of these waters is such that the dissolved oxygen contained therein is about 70% of the amount of saturation. Inevitably, in the vicinity of sewer outlets, the pollution will be greater, but with that standard it is reasonably certain that the worst portions of the waters will not be so impure as to be offensive or harmful. As far as is known to the writer, it is only within recent years that well-founded complaint has been made of offensive conditions anywhere in the harbor. He remembers that as late as 1890 shad were plentiful and excellent in the East and Hudson Rivers.

The importance to New York of this question is recognized. To study it seriously and logically a standard of purity should be fixed upon; the capacity of the various parts of the waters to care for sewage without consequent pollution below that standard should be determined; the amount of purification required for sewage in excess of that capacity should be computed; and the most economic methods of securing that degree of purification found.

THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.

Paper No. 61.

PRESENTED DECEMBER 28TH, 1910.

CONSTRUCTION OF THE CROTON FALLS RESERVOIR—NEW YORK CITY WATER SUPPLY.

BY FREDERICK S. COOK,* M. M. E. N. Y.

WITH DISCUSSION BY
ARTHUR S. TUTTLE, JOHN F. COGAN, C. ELMORE SMITH, ROBERT RIDGWAY, WALTER CREUZBAUR, GARDNER L. VAN DUSEN, ALFRED D. FLINN, GEORGE A. TABER AND FREDERICK S. COOK.

The Croton Falls Reservoir, at the present time, can be considered complete and ready for the storage of water during the coming season, although a small amount of cleaning up and the finishing of the final estimate remains to be done. This reservoir is the second largest of a system of twelve new storage basins built in the Croton Watershed, the latest in the development of a plan which was proposed in 1858-59, having for its object a complete conservation of all water obtainable from the above shed, to be drawn upon by New York City when required. (See Plate 65.)

The geographical center of the watershed is located in Latitude 41° 21′ 45″ North, Longitude 73° 41′ 15″ West, distant in a direct line 50 miles northerly from the New York City Hall, and 15 miles easterly from the Hudson River, north of Peekskill. It has a length, north and south, of 30 miles, and a width, east and west, of 16 miles. The area by a survey made in 1858 is 360.44 square miles.

* Division Engineer, Department of Water Supply, Gas and Electricity.

Except for a small area of 20¾ miles, lying in the State of Connecticut, the Croton Watershed is within the Counties of Dutchess, Putnam and Westchester, State of New York. Of this vast area of land, New York City owns in fee, 8$\frac{8}{10}$%, or 32.73 square miles. The "run off" from this watershed forms the "Croton River." In 1685 this river was known as the "Kitchawan" (a wild, dashing stream). It derives its present name from an illustrious Sachem "Kenotin" who ruled over the territory at the mouth and along the river. It has been said that the name "Kenotin" means "wind." It has shown on many occasions that it was a "wild and dashing stream." It has its source on "Quaker Hill" in Dutchess County, at an elevation of 1 393 ft. above high water at New York City. From thence it flows southerly and westerly in a serpentine course through its East Branch, out of Dutchess, across Putnam and Westchester Counties, a distance of 43½ miles, discharging its water into the Hudson below Croton Point, north of Ossining. It has many tributaries. The principal streams north of the Muscoot and Titicus, are known as the East, West and Middle Branches, confluent at a point a little west of the village of Croton Falls in Westchester County, 18¾ miles up-stream from the New Croton Dam.

The Croton Falls Reservoir was given its name from a beautiful cascade located on the East Branch of the river, northeast of the village bearing the same name. The dam and reservoir are located in the County of Putnam, just north of the northerly line of Westchester County, and is in the center of the Croton Watershed, as heretofore described. (See Plate 62.) The watershed above the Croton Falls Reservoir, Main Dam, has an area of 161.74 square miles, of which 84.2 are in the East Branch Valley and 77.54 are in the valleys of the West and Middle Branches.

The new reservoir consists of a main storage basin of 14 865 million gal. capacity, located in the valleys of the West and Middle Branches, formed by a concrete masonry dam constructed across the West Branch, at a site locally known as "The Hemlocks," about one mile up-stream from the confluent point of the East and West Branches, above referred to, and about a half mile down-stream from the point where the Middle Branch of the Croton flows into the West Branch. (See Plate 61, Figs. 1 and 2.)

There is also an auxiliary reservoir with a diverting dam, built

of earth, with a concrete masonry core wall, constructed across the East Branch at Dean's Corners, midway between the villages of Croton Falls and Brewster. (See Plate 70.) This diverting dam reservoir has a capacity of 888 million gal. It was built only for the purpose of diverting the waters from the East Branch watershed through an open paved "Connecting Channel" 3 522 ft. long, into the large reservoir in the westerly valleys, thereby providing additional storage for the three watersheds, the East, West and Middle Branches, to the extent of 15 753 million gal. The small storage of 888 million gal. impounded back of the "Diverting Dam," is to be drawn only at such periods as necessity requires.

There was in the East Branch valley, before this new construction, a total storage capacity of 9 643 million gal. or 125.4 per square mile, and in the West and Middle Branch valleys a capacity of 18 085 million gal. or 294.3 per square mile. Since the construction of this new reservoir, with its "Main Dam" and large storage reservoir in the westerly valley, joined by the "Connecting Channel," with its "Diverting Dam" and storage basin in the East Branch valley, the conditions are changed. New storage of 15 753 million gal. has been provided, making a total storage capacity above the Croton Falls Main Dam of 43 861 million gal. It may be seen that the unbalanced storage of 125.4 and 294.3 million gal. per square mile, formerly existing in the east and west valleys respectively, has been corrected. There is now a storage capacity of 271 million gal. per square mile of watershed above the Croton Falls Dam. By the completion of this reservoir the storage capacity of the entire Croton Watershed above the New Croton Dam is 104 442 million gal., or 289.8 for each square mile of the 360.44 contained therein.

In addition to the above, 1 000 million gal. of water stored, in private lakes and ponds, might be obtainable by purchase in case a water famine should occur. This amount is about 3 days' supply.

It may be asked, why should not this main dam have been built at or below the confluence of the East and West Branches of the Croton River, which would have obviated the necessity of constructing the diverting dam and connecting channel. It was at first proposed to construct the dam across the Croton River below the confluent point, at a site half way between Croton Falls village

FIG. 1.—CROTON FALLS DAM—COMPLETED.

FIG. 2.—CROTON FALLS DAM AND SPILLWAY.

and Purdy Station, at what is known as Dean's Bridge. After a study it was found that to build at this site would require the reconstruction of from 4 to 5 miles of the "Harlem Division" of the New York Central & Hudson River Railroad from a point north of Goldens Bridge nearly to the site of the present Diverting Dam. This would be for a double-track road, over expensive steel bridges of great length and over heavy fills. It would also necessitate the destruction of very valuable mills and water power on the East Branch of the Croton, together with the complete wiping out of the village of Croton Falls, and a large area of valuable land above the site then proposed.

The following table may be found interesting and instructive:

CROTON WATERSHED.

AREA = 360.44 SQUARE MILES.

(See Plate 65.)

Above.	Area in Square Miles.	Storage, in Million Gallons.	Storage per Square Mile, in Million Gallons.
Boyds Corners Dam	21.48	2 927	136.6
Carmel Dam	40.94	13 930	340.2
Middle Branch Dam	20.51	4 155	202.5
Bog Brook Dam	3.67	4 400	1 198.9
East Branch Dam	76.90	5 248	68.2
Diverting Dam	84.20	10 581	125.4
Croton Falls Dam	161.74	43 861	271.1
Amawalk Dam	18.32	8 226	449.0
Titicus Dam	22.80	7 617	334.0
Cross River Dam	28.58	10 928	382.2
Muscoot Dam	304.06	75 541	248.4
Old Croton Dam	338.82	77 541	229.0
New Croton Dam	360.44	104 442	289.8

The extra cost over the present site, due to the location at Dean's Bridge, would have amounted to $2 000 000. It was therefore decided that the present site was the most desirable and inexpensive.

The construction of this reservoir was finally decided upon and ordered October 3d, 1905. The property maps, contract drawings and specifications were then prepared under the direction of Walter H. Sears, Chief Engineer, and Professor Wm. H. Burr, Consulting Engineer, by George A. Taber, Assistant Engineer in charge of the main office. The condemnation proceedings were then inaugurated

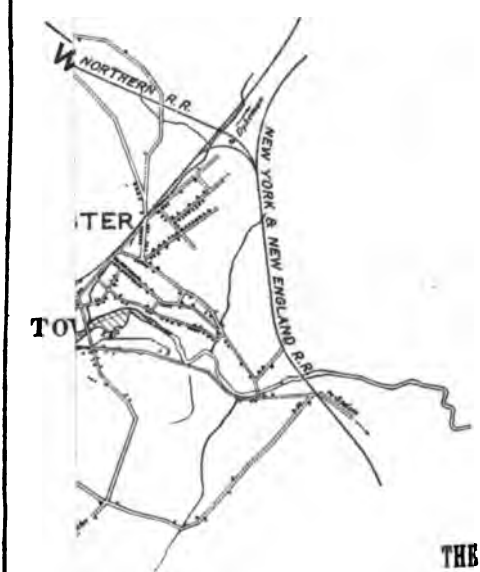
to acquire the necessary 2 391.5 acres of land. After the preliminary work in the field was completed by George G. Honness, Division Engineer of the Katonah Division, a new division, "the Croton Falls," was established June 26th, 1906, and placed under the writer's direction as Division Engineer. The work was then divided into three natural subdivisions, as follows: Corps No. 1, Main Dam, etc., C. Elmore Smith, Assistant Engineer; Corps No. 2, Diverting Dam, Connecting Channel, etc., William Hauck, Assistant Engineer; and Corps No. 3, Highways, etc., C. E. Benedict, Assistant Engineer; each of these subdivisions was supported by an able and willing quota of assistants. The detail surveys and laying out were then taken up.

The work was advertised, seven bids were opened August 7th, 1906, the work awarded to James Malloy & Co. (next to lowest bidder) and the contract signed on August 23d, 1906. On August 25th Mr. James Malloy, senior member of the above company, died. The work, however, was started promptly, ground broken September 2d, 1906, and carried on by the above company, until a reorganization was effected. On March 5th, 1907, the contract was assigned to the Croton Falls Construction Company, which carried out the work to completion.

Work to be Done.

The contract called for doing all the work necessary for completing the reservoir, in all its parts, ready for use. It consisted principally of the construction of a main dam and a diverting dam, with reservoirs, and an open channel 3 522 ft. long connecting them; 2½ miles of standard gage construction railroad for transporting the plant and materials from the Harlem Railroad switch at the diverting dam to the main dam; 14½ miles of new highways to replace an equal length of old highways, which will be submerged when the reservoirs are put in commission; 14 large concrete highway bridges, with many masonry and other culverts in connection therewith; three 17-ft. tunnels under the roadbed of the Harlem Railroad, for the passage of water to the connecting channel; 21 miles of stone wall boundary fencing, to enclose the 2 391.5 acres of property acquired by the City for this work; 21½ miles of wooden

PLATE 62.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
COOK ON CONSTRUCTION OF THE
CROTON FALLS RESERVOIR.



CITY OF NEW YORK.

THE AQUEDUCT COMMISSIONERS.

CROTON FALLS RESERVOIR (K)

PLAN OF LOCALITY

1907

CHIEF ENGINEER.

guard rail and other fencing, placed along the embankments and bounds of the new highways; the clearing off of all the trees, brush, old fences and buildings from the 1 600 acres of land to be flooded; the construction of a new filter bed below the diverting dam, with about 2 miles of twin 15-in. tile pipe sewer, to replace the present filter field or bed, now used in connection with the electrozone plant, maintained by the City of New York for the treatment of sewage discharge from the village of Brewster, the new reservoir inundating the greater part of the old bed, and necessitating the removal of the original field to a safer and better location below the diverting dam.

PLANT.

The plant obtained and used for this work, was, generally speaking, new and up-to-date. Its selection and installation indicated experience, good judgment and careful study on the part of the contractor, which was shown during the work by the results.

There were laid and used on the work nearly 21 miles of tracks. Most of this was with 60-lb. rails, but a small amount was with 30- and 80-lb. rails laid for special work.

Of the total of 21 miles, 2½ miles was laid of standard-gage track from the diverting dam, switching from the New York Central & Hudson River Railroad, Harlem Division, to the main dam. Over the ties of this 2½ miles of road a third rail was laid, forming a 36-in. narrow-gage track, which connected with all other narrow-gage construction tracks. This allowed the Vulcan and Davenport narrow-gage locomotives to do service in moving freight cars from the Harlem Railroad along the standard gage, as well as moving narrow-gauge cars over the entire system, about the dams, yards, quarry, sand pits, crusher, sand and stone storage, cement sheds, block yard, under cableways and derricks, and from the steam shovel excavations at the dams and from cuts to the fills.

The rolling stock employed on the work was of 36-in. narrow gage, and consisted of the following: 14 Vulcan and 2 Davenport locomotives, 36 construction flat cars, 3 box cars, 1 pay car, 1 observation car, 30 4-yd. one-way and 56 4-yd. two-way side-dump cars, 3 steam shovels (2 70-ton Bucyrus No. 5, with 2½-yd. dipper, and 1 35-ton Marion, with 1¼-yd. dipper), 2 Cyclone and 1 Keystone

traction drills, 1 10-ton Buffalo-Pitts steam roller and one Iroquois 5-ton steam roller, and 1 road machine.

For repairing the plant there was a well-equipped machine shop located near the main dam, with a blacksmith shop attached, where most of the repairs were made. In addition to this there were other blacksmith shops, located at points most convenient. There were 16 Troy bottom-dump wagons, a "water wagon," 45 carts and 102 head of working stock, consisting of horses and mules, the latter being preferred on this work. There were also two large modern barns or stables, centrally located, together with blacksmith and harness repair shops.

There were 5 crushers, 1 No. 10 and 2 No. 6 McCully, and 2 portable 9 in. by 15-in. Climax, with 9 in. by 12-in. engines.

There were 8 concrete mixers used in all; 3 Haines, 1 No. 2½ and 1 No. 5 Smith, two ¾-yd. Ransome, with 7 in. by 7½-in. engines, and 1 No. 33 Municipal.

The boiler capacity on the entire work amounted to nearly 2 500 h.p. This proved ample, as very little if any delay was caused through lack of power. The principal boilers were 6 vertical water tube of 260 h.p. each (total 1 560), one located below the main dam (see Plate 63, Fig. 1), used for pumps, drills and derrick hoisting engines, the other five at the main station, about midway between the main dam and the cyclopean stone quarry. At this power station were located the large crushers and the compressors. In addition to these large boilers there were 15 or 16 stationary, upright and horizontal portable boilers of various types and sizes, ranging from 15 to 100 h.p. each.

The compressors used were five in number, 1 Ingersoll-Sergeant, Class "F," 3 Ingersoll-Sergeant, Class "H," 15 in. by 28 in. by 25¼ in., and 1 Vulcan straight line, 20 in. by 20 in. by 30 in., located at the above-mentioned power station, from which air was supplied to the drills used in the quarry and to those at the main dam, also to the cableways, derrick hoists, etc. Five air receivers were used in connection with the compressors, 1 21½ ft. by 5 ft. with 8-in. connections, 2 13 ft. by 5 ft. with 8-in. connections, 1 13½ ft. by 5 ft. with 4-in. and 5-in. connections, and one 7 ft. 7 in. by 3 ft. with 2-in. and 4-in. connections. The piping for

FIG. 1.—EXCAVATION AT MAIN DAM. FIRST STAGE OF DERRICKS.

FIG. 2.—MASONRY AT MAIN DAM. SECOND STAGE OF DERRICKS

conveying the air (under 90 lb. pressure) was from 8 in. to 2 in., which conveyed it southerly 2 500 to 3 500 ft. to the main dam site and across the valley thereat, also to and about the quarries located 1 200 ft. northerly from the power house.

There were in use 25 guy derricks, with masts ranging from 60 ft. to 90 ft. in height, carrying booms varying from 60 to 90 ft. in length, and 16 to 20 stiff-leg derricks, with 40-ft. masts and with 70-ft. booms. (See Plate 63, Figs. 1 and 2.)

Two 10-ton Lidgerwood cableways, with cables 2¼ in. in diameter, were used at the main dam, spanning the valley, 1,434 ft., with head towers at the south end, 73 ft. high, and tail towers at the northerly end 106 ft. high. The towers were mounted on individual trucks. The engines, 12¼ in. by 15 in., with drums 60 in. in diameter and 42 in. long, were carried on the rear of the head tower truck. These trucks and towers were movable laterally, 22 ft. to the right, and 112 ft. to the left of the dam line, bringing the cables within 45 ft. of each other. (See Plate 64, Figs. 1 and 2.)

There were 37 hoisting and other engines, generally of the Lidgerwood type, 7 in. by 10 in. D. C. D. D.; 3 American type, and 1 Mundy, D. C. D. D. of 7 in. by 10 in., and other sizes, together with one 300-h.p. Corliss engine, 16 in. by 36 in., at the power station.

There were used on the work one Davidson 14 in. by 8½-in. pump, with 6-in. suction and 5-in. discharge, 1 Dean duplex tandem compound, 14 in. by 14 in., 12 in. suction and 10 in. discharge, 3 belt-driven centrifugals, 8 Blake, single and duplex, 10 Cameron, 3 Pulsometers and 2 pumps of the Emerson type.

The above gives a fair idea of the principal parts of the plant engaged on this work. The cost of the contractors' construction plant, including installation, renewals, etc., less the amount recovered from salable parts, will be about $425 000, or about 10% of the cost of the work done under the contract, which will be approximately $4 250 000, not including the cost of the land, engineering and superintendence.

From present estimates, the engineering and superintendence of the above work in the field, not including the work done in the New York main office, will cost about 5% of the above value of the construction work.

Construction. Main Dam.

The main dam, which is built across the West Branch of the Croton River at the "Hemlocks" site, as previously described, is constructed entirely of concrete and cyclopean masonry. The concrete was mixed in the proportions of 1:3:6, and in the cyclopean masonry there is about 33% of large stone and 67% of concrete. The profile or section of the dam (see Plates 66 and 67) is heavier than that of other dams built in the Croton Watershed, in fact, it is even heavier than that calculated and used for the Cross River Dam, completed three years ago, which increase was made to overcome the action of ice, the reservoir being in an exposed location.

The height, from the rock foundation to the top (Elevation 322), is 173 ft. The exposed portion above ground is 97 ft., the width at the top is 23 ft., at Elevation 280.80, 33.07 ft., and at Elevation 210, 72.72 ft. The up-stream face is vertical from Elevation 210 to Elevation 322; below this point it has a batter of $\frac{1}{4}$ to 1. The down-stream face batters $\frac{3}{4}$ to 1 from the foundation at Elevation 150 to Elevation 210, then to Elevation 280 it has a batter of $\frac{56}{100}$ to 1. From thence it curves outwardly with a radius of 79 ft. to the top, where the thickness is 23 ft. with the necessary cornice and fence coping, admitting of a 22-ft. roadway across the dam. (See Plate 67.) The dam on the crest line is 1 100 ft. in length, with a 5-ft. concrete core wall at its northerly end extending 50 ft. into the hillside, built down in earth and rock trench to a secure or tight bottom.

At the southerly end the dam terminates in a bastion 35 ft. in diameter containing a stop-plank storage room. From this bastion the waste weir or overfall dam extends 700 ft. easterly up-stream, and is built into the rocky slope on the southerly or left side of the reservoir. (See Plate 68.) This waste-weir dam is of concrete and cyclopean masonry, built up with the latter from deep trench, cut well below the grade of the spillway channel, to the channel grade; from thence it is built up with reinforced concrete, having a vertical face on the reservoir side and on the down-stream side stepped with concrete blocks of 2 ft. rise and from 12 in. to 3 ft. tread, varying with the section of the dam, which is, at its maximum, about 24 ft. wide on the base and about 20 ft. high. (See Plate 70, Fig. 2.)

FIG. 1 —MAIN DAM, MASONRY PROGRESS. THIRD STAGE OF DERRICKS.

FIG. 2.—MAIN DAM, MASONRY PROGRESS. THIRD STAGE OF DERRICKS.

This concrete section is coped at the top with granite, forming a weir of stone, 2 ft. 10½ in. by 7 ft. 5½ in., each stone doweled into the concrete structure below. The crest of the spillways of both the main and the diverting dams is at Elevation 310, the former carrying flash boards 2 ft. high to Elevation 312. The waste weir at the main dam just described is 700 ft. long. At the diverting dam the waste weir is 1 000 ft. long and of the same design and material as at the main dam. Both are provided with waste channels of ample dimensions for conducting the flood waters below the dams. These channels were excavated mostly in rock. (See Plates 68 and 70.) The bottoms and sides, where necessary to prevent erosion, are either concreted or paved, the former being applied to decomposed rock surfaces, and the latter to earth bottom and slopes. The geological formation of the country in which this work was done has no particular features other than those found in any of the adjoining counties. At the main dam site many borings and test pits were made, which proved generally reliable, as was observed during construction. In the valley, at the original river level, was found a deposit similar to that found along many other large streams, a fine washed sand with few boulders. The sand was too fine for use, and coarser sand was obtained from banks above the river level. The top deposit of 2 ft. being rich soil, it was excavated and stored, and later used for soiling the finished grounds about the dam. The 3 to 5 ft. of deposit down at the rock surface would be classed as glacial drift. The surface of the bed rock was ground smooth by the action of the floods. This bed rock, when excavated, proved to be laminated, with a dip of 30° to center of the valley, and of gneissic formation approaching granite. The seams between the layers were filled by nature with a remarkably fine, tough clay. The surfaces of the bed rock on the right of the sub-channel were ground down to thin edges. When cleared of the superincumbent mass and exposed for a time to the rays of the sun, this rock, over an area of approximately a quarter of an acre, would crack and rise from its original bed with a snap and a boom, the cracks crossing the layer and the seams opening from ½ in. to an inch. When these layers were "barred and wedged" off and removed, the snap and boom again occurred, until the rock was taken out to a depth of from 2 to 8 ft. The cause of this was the change in temperature from 50°

to 125°. The above did not take place at the left or south side of the original sub-channel, where the rock was also of gneissic formation, but of much poorer quality, being decomposed and somewhat blocky. The rock higher up, both on the right and left slopes, particularly on the left or south side, was blocky and full of seams, and great care was exerted to see that the excavation in rock was taken out below these seams, in order to secure a tight bottom, which we fully believe was obtained.

The construction work at the main dam was started in the fall of 1906. The soil was removed from the site of the dam, and the excavation for a temporary channel of 1 000 million gal. capacity was made. Through this channel the river was carried during the construction of the dam. It was located north of the original river bed, along the foot hills on the right side of the valley, extending from a point on the river 600 ft. above the dam, to a point on the river 800 ft. below the dam. Of this 1 400 ft. of new channel, a length of 800 ft. was in timber flume, 350 ft. above and 450 ft. below the dam line. The flume was 24 ft. wide by 8 ft. 2 in. deep. The central portion, where it passed over the excavation for the dam, was supported on steel columns founded on rock at the bottom of the excavation; this steel support for the flume was left standing and the masonry of the dam built about it. During the time of excavating below the surface of the river, the flume was tested beyond its capacity by a flood. The water rose at the intake, filling and just overflowing the flume, damage and delay being prevented by the quick action of a hundred men placing sand bags along the upper portion of it, up-stream from the excavation. The flume did the work nature required of it, but did not show within 10% of what man expected of it. The cause was that there were too many angles built in its course, producing jamming and rolling which obstructed unexpectedly the free flow through it. Had the sides of the flume, at the upper end, been a foot or more higher, or a little farther apart, the flood on this occasion would have been taken care of. The channel approach to the flume, and where it discharged again into the channel, was 70 ft. wide, with paved bottom and slopes. The flume was built of heavy timber, 8 in. by 12-in. sills, 37 ft. long, 8 in. by 8-in. side posts, with 6 in. by 8-in. exterior knee braces. The tops of the

PLATE 65.
THE MUNICIPAL ENGINEERS
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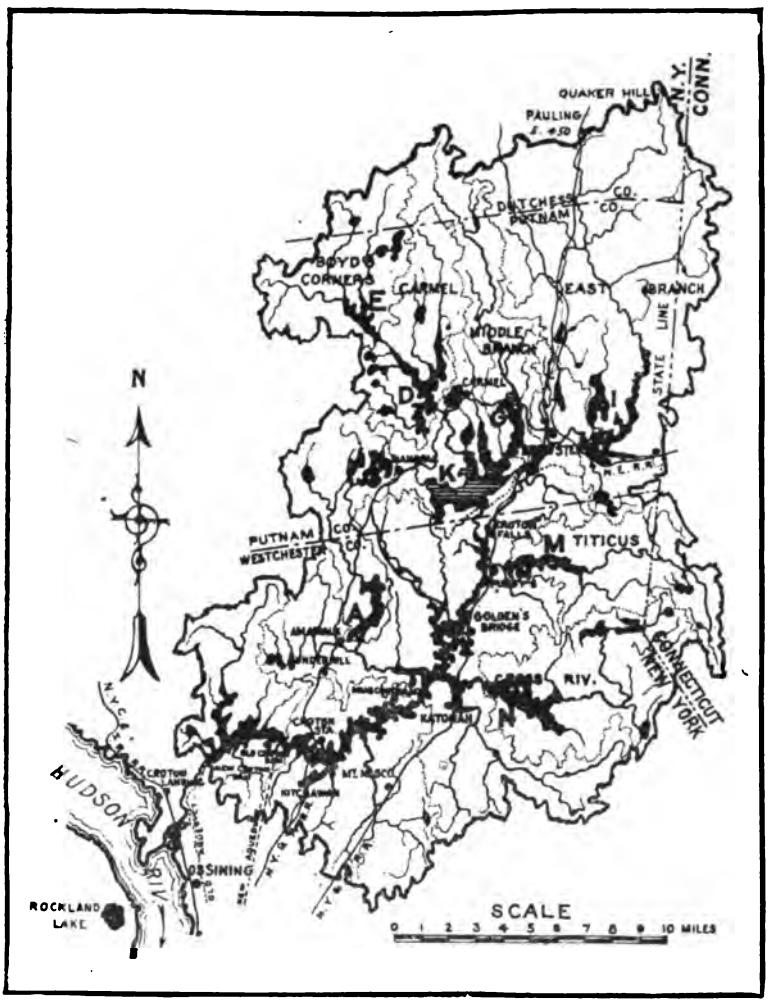
COOK ON CONSTRUCTION OF THE
CROTON FALLS RESERVOIR.



CROTON WATERSHED.
Area, 360.44 Square Miles.

posts were tied and braced transversely with 10-in. round timbers with 1-in. tie rods added, and all matched, mortised and tenoned together and then spiked.

The bottom and sides of the timber flume were covered with 2-in. undressed spruce plank, laid closely together and covered with two thicknesses of tarred paper, upon which were nailed 1-in. tongued and grooved yellow pine boards, the joints being then painted with asphalt paint. This construction proved to be first class, as very little leakage into the excavation came from the flume proper. The valley, however, being naturally formed of sand and gravel, allowed more or less water to percolate from above and below into the excavation for the dam. (See Plate 63, Fig. 1.)

The quantity of earth excavated at the main dam was 280 000 cu. yd. and of rock 95 000 cu. yd., most of the former being taken out by a 70-ton Bucyrus steam shovel with a 2½ yd. dipper, which was attended by 3 locomotives and trains of 5 4-yd. cars each. The material was generally taken out by the steam shovel at an average rate of 500 cu. yd. per day of 8 hours, the maximum day's work being 1 200 cu. yd. The excavated earth was moved up-stream from the dam and wasted in dump, which dump was later graded off, forming yard area upon which the "concrete facing blocks" were manufactured.

There were three reasons for moving the excavated earth and rock up-stream: 1st, the filling of the low land or river bottom for a block yard; 2d, to prepare for the supply tracks approaching the dam, and 3d, that there might be no unsightly dumps below the dam to be regraded later or left to mar the landscape. (See Plate 61, Figs. 1 and 2.) There was nothing unusual in the excavation work at the main dam. The earth was taken out to a maximum depth of 44 ft., with slopes of 1½ to 1, and to such an extent in width as would leave a 10-ft. berm at the surface of the rock. The rock was excavated, at maximum depth, 17 ft. deep, with slopes ¼ to 1, making a total depth of trench from the surface of 61 ft. After the steam shovel had done its work in earth, it was used for taking up the "muck" from the rock excavation in the bottom and at the south end of the dam site. The earth and rock which could not be handled with the steam shovel was removed by the 90-ft. guy derricks and placed on cars or piled up on either berm, convenient for handling.

When sufficient bottom had been properly prepared by making sure that no seams or holes had been left untreated by grouting or otherwise, the building up of the masonry was begun. On April 15th, 1908, the excavation had been finished to an extent which permitted the laying of the first concrete facing blocks for the dam.

The material of which the dam and its appurtenances were constructed, was handled by the 2 Lidgerwood cableways, suspended so as to clear the crest of the dam 40 ft. under a load of 15 tons. The hoisting speed was 300 ft., and the trolley speed 1 200 ft. per minute. There were also two lines of guy and stiff-leg derricks, one line on either side of the excavation. The guy derricks were located about 170 ft. apart, and the stiff-leg derricks 104 ft., and were placed in such position as would allow a free swing of the booms, in covering any part of the work. (See Plates 63 and 64.) The guy derricks were used during excavation and at the beginning of the laying of masonry, but when the guys interfered with the working of the cableways, this type of derrick was replaced by the stiff-leg type, of which there were seventeen in number. The cableways were used only for delivering, in the two-and-one-half yard buckets, the concrete mixed by the Haines mixers, located at the south end of the dam (see Plate 69, Fig. 1), the derricks then taking the buckets and placing the concrete therein where required. These derricks also handled the "cyclopean stone" and "facing blocks," taking them from the cars and placing them on the dam as needed.

Steel derrick towers, six in number, with 25 by 50-ft. bases, were designed to be used to construct the dam to about the original ground surface. They were to have been set up on the rock bottom and the tower built to a proper height to support the derricks and hoisting engines to be used in handling and placing the materials of construction. These towers were to be built in with the masonry of the dam and grouted as the work progressed. It was intended by the use of these towers to accelerate the progress and incidentally act as a reinforcement to the structure. Before the masonry was commenced it was argued and believed, first, that by the use of these towers there would be great interference, caused by the swinging of the booms across the paths of the cableways, thus retarding the work and possibly causing accidents; second, that there would be a loss of time in placing a reduced quantity of

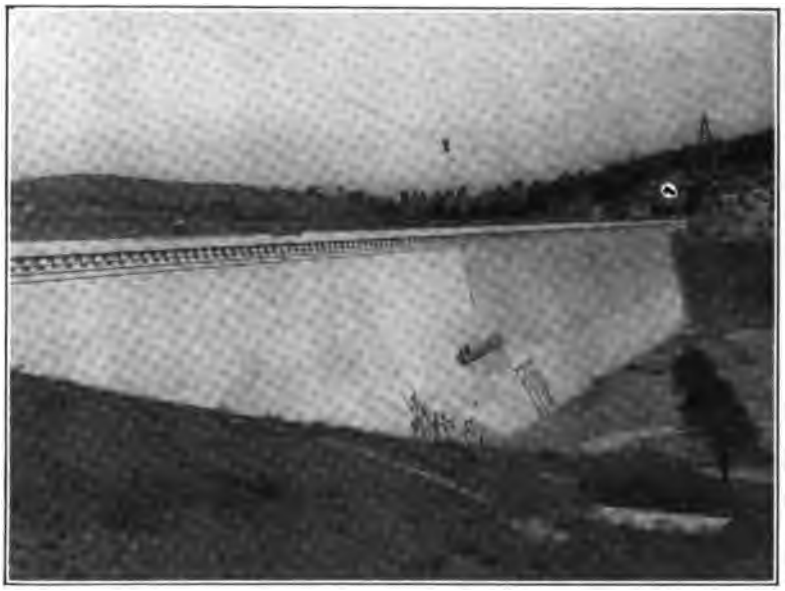


FIG. 1.—CLEANING DOWN FACE OF MAIN DAM.

FIG. 2.—SECTION OF MAIN DAM, SHOWING THE CYCLOPEAN MASONRY. CONCRETE FACING BLOCKS, AND REINFORCING STEEL.

"cyclopean stone," and at an increase in cost in placing the concrete and stone used within the legs and bracing of the oblong tower structure; and third, the excess in concrete used within the steel structure would entail an additional cost. The towers were therefore omitted, effecting a saving to the City of $30,000 and a saving to the contractor, in not having to use them. The stiff-leg derricks were, as has been said, placed in line on either side of the excavation, upon individual framed towers, so as to avoid interfering with the cableways. The first position was below the surface, the second at the surface and the third at a height from which the booms could complete the dam to its top. (See Plates 63 and 64.) The upper coping or fencing base was cast in place, after the cornice members were set.

The principal items of material handled by the above plant at the dam were as follows: 245 000 cu. yd. of cyclopean masonry, 30 000 cu. yd. of concrete facing blocks, 15 000 cu. yd. of concrete masonry, 540 cu. yd. of dimension stone, 230 000 bbl. of cement, 575 tons of reinforcing steel, and 180 000 cu. yd. of refilling.

The cyclopean masonry used in the dam contained stone of from 1 to 3 cu. yd. each, or as large as could be handled by the derricks, and concrete of 1:3:6 mixture. The stone was quarried from a point of hill, three-fourths mile up-stream, and was brought down on flat cars (as were also the concrete facing blocks from the block yard), and swung into place upon a bed of concrete. The stone was then fully worked and jarred, with bars, until perfectly bedded, the concrete having been previously brought in by the cableways, placed and thoroughly worked with spades to properly prepare it for receiving the stone, and allow entrained air to escape. All the stones were laid in this manner, placing them within six inches of adjoining stones, filling the voids with soft, wet concrete, forked or spaded into the interstices between the large stones and spawls. The quantity of large and small stone used was on an average 33%, and that of concrete 67% of the mass.

The cyclopean masonry was generally built up with the concrete facing blocks, from a well-prepared rock foundation. The concrete facing blocks were built one or two courses in advance of the cyclopean masonry, in order to retain any soft mortar which otherwise would have run to waste over the sides of the structure.

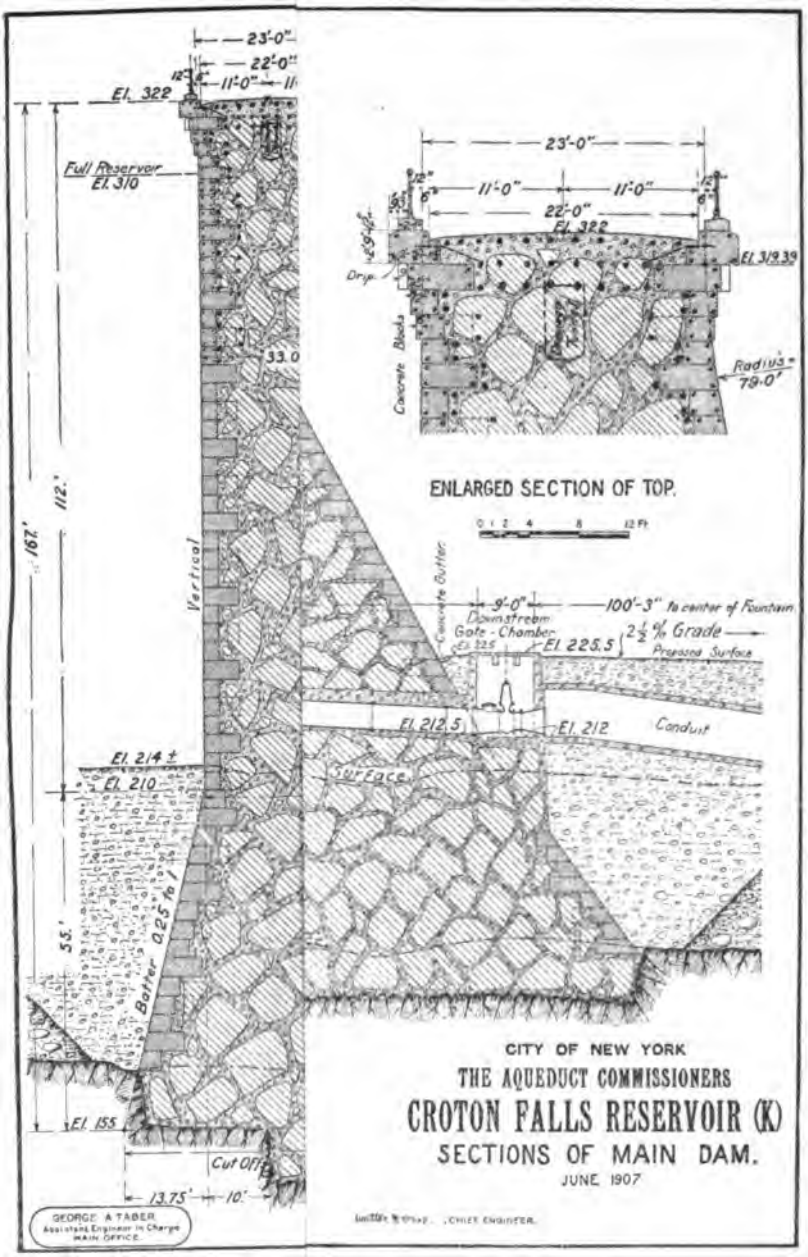
The masonry was carried up uniformly, except at the crossing of the flume, where the courses were built up to the under side of the flume and thence racked off. The gap was left until the water in the river was low, when the flume was quickly removed and an opening or culvert 12 ft. by 12 ft. left for the river flow, while the masonry as being carried up to the adjoining courses and to a finish. Later the opening was filled with rich concrete, 1:2:4 mixture, and when set, the voids were grouted under 150 lb. pressure.

Reinforcement.—The masonry in the dam was reinforced by building 1¼-in. square steel rods into the face portions of the structure, from Elevation 280 to Elevation 322, and into the upper 5 ft. below the roadway. These rods were forged at both ends to a right-angle hook, so as to join and lie in a direct and continuous line, forming a tension member. Care was taken to have the hooks closely fitted together, even to inserting metal wedges where such was not the case.

These rods were placed back of the facing blocks, two at each joint, two 6 in. back of the stretcher, and two 6 in. back of the tails in the header course. In all facing blocks laid in the portion of the dam above Elevation 280, four ¾-in. rods were cast in the blocks, located 6 in. from the corners of the blocks. This was done to force shrinkage cracks, should they occur, to the vertical joints between the blocks, rather than have them cross the block. This plan of placing the reinforcement in the face portions and from Elevation 280 to the top, rather than placing it uniformly throughout the upper portion of the structure, as was done in the Cross River Dam, was adopted after experience gained at the New Croton Dam, where a season crack occurred crossing the top of the structure. This crack was first filled with "blueing water" and then the masonry cut out to where the blueing had settled, the result of which showed that the crack was deeper at the top and faces than at the center. At the Croton Falls Dam observations were made by the use of pipe thermal wells, 8 in number. The "thermal records" thus taken showed only slight changes within, while extreme changes were taking place without, thereby confirming the observations at the New Croton Dam.

After passing through the cold weather of the winter of 1909-10, the heat of last summer and the present cold snap, close observations show that the work has been well done and that the reinforcement

PLATE 67.
THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. COOK ON CONSTRUCTION OF THE CROTON FALLS RESERVOIR.



was properly placed in position, although there have recently appeared three slight contraction cracks.

Concrete Blocks.—The concrete blocks used in the facing of the main dam, were manufactured in a yard about a half mile above the dam, made by grading off the spoil from the main dam excavation. In this yard four rows of 8-ft. ties were laid down level and three lines of 3 in. by 12-in. string-pieces spiked to each row of ties, which were then thoroughly tamped, forming a firm foundation for the pallets. There were two rows of boxes or forms together and one on either edge of the yard at proper distance to allow clearance for narrow-gage tracks between the central and outer rows of forms.

On these tracks traveled 4 narrow-gage 4-wheel trucks, two on each track, on which was erected a heavy framed platform transfer table upon which were mounted four bins or hoppers to receive the concrete. The concrete (1:3:6) was mixed by a Smith mixer located at one side of the yard and passed in two-yard buckets to the platform hoppers with guy derricks with 75-ft. booms, placed at lapping intervals along either side of the yard. These derricks were also used to pile up the finished blocks for seasoning. The block boxes or forms being placed in line across the yard as well as in line down the yard, the transfer table and hoppers with discharge gates could be brought over four boxes at once, the four rows of gates opened and the four boxes filled simultaneously. The boxes in one line being full, the transfer table was moved backward with pinch bars the required distance to bring the hoppers over the next line of boxes. This method of placing the concrete was found very economical. Seven men were employed on the transfer table and boxes, to handle the full output of the mixer, turning out 108 blocks per eight-hour day, averaging 2.3 cu. yd. to the block.

The concrete in blocks was allowed to set unmoved for from 24 to 72 hours, depending on weather conditions. They were then picked up and piled for ninety days to season, and thoroughly wet down each day during this period. The blocks were generally cast face down on steel plates, but those cast with the face on the side of the box showed no difference in texture, and the latter method was found more convenient in the case of blocks with a heavily battered face. The largest blocks made were 3 ft. by 3 ft. by 8 ft.; those above Elevation 280 were reinforced with ¾-in. square steel rods.

Through the main dam there are 3 48-in. pipes forming the

blow-off or outlet. These pipes start from individual chambers, with openings from the reservoir side at three different levels, controlled by sluice gates, provided with stop-planks, and the openings guarded by screens. The gate chambers and superstructures are on the up-stream face of the dam. At the down-stream or outer toe of the dam the pipes pass through a stop-cock chamber, where they reduce from 48 in. to 36 in., in which contraction there are 36-in. valves, with which the water can be controlled. From these valves the 48-in. pipes pass into a reinforced concrete conduit, 26½ ft. wide by 7½ ft. high, gradually reducing to a horseshoe shape 8 ft. by 7½ ft. at its discharge end, where it passes into a closed sub-chamber 28 ft. in diameter. Through the roof of this chamber, there are six circular openings, two 4 ft., two 5 ft. and two 6 ft. in diameter, together with a 6-in. pipe opening at the center. Through these openings the water bubbles up into a 70-ft. circular fountain inclosure, and thence into the forebay 70 ft. wide and 120 ft. long. This terminates at the measuring weir, built for a flow of 500 million gal. per day. The normal flow of the river at this point is about 200 million gal. per day; in flood during this construction, it was 900 million gal. per day. (See Plates 61 and 68.)

Diverting Dam.

The diverting dam previously referred to is built across the East Branch of the Croton River at Dean's Corners, two miles below the Village of Brewster. (See Plate 70.) Its length is 1 185 ft., height 55 ft. above the surface, and 15 ft. wide on the top at Elevation 322. On the up-stream face it has a slope of 2 to 1, paved with 18 in. of dry stone laid on 6 in. of broken stone up to Elevation 216, with a 5-ft. berm in the slope at Elevation 295. The down-stream slope, 2 to 1, is soiled and grassed from the top, Elevation 320, to Elevation 305, where a berm for a new highway, 23 ft. wide, is constructed, and from this elevation down to Elevation 285 the slope is 1½ to 1, as on other highway embankments.

This dam has a concrete core wall, 5 ft. thick on top at Elevation 313, with a batter of 1 in 20 on either side, till a thickness of 9 ft. is reached near the original surface of the ground, where the wall has an offset on either side. Below this point the core wall fills a 10-ft. trench, which was sheathed vertically down into the rock,

PLATE 68.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
COOK ON CONSTRUCTION OF THE
CROTON FALLS RESERVOIR.

FIG. 1.—MAIN-DAM FOUNTAIN, MEASURING WEIR AND SPILLWAY.

FIG. 2.—MAIN DAM, SHOWING WASTE-WEIR, STOP PLANKS, AND SPILLWAY CHANNEL.

completely cutting off all flow of water. The timber bracing was removed as the concrete core wall was built up.

The construction work at this dam was begun at the same time as was the work at the main dam. The control of the flow of the river was accomplished by excavating a temporary channel through earth and rock, 24 ft. wide, to the east of the former river bed. The down-stream end, after passing the site of the waste weir or over-fall dam, was made as a part of the waste weir channel. With this there was constructed a guard or temporary earth dam of proper proportions to deflect the river from the site of the permanent dam.

The trench for the concrete core wall was excavated down through glacial drift, except in the centre of the valley, where it was through fine, water-bearing sand and gravel. The maximum depth of trench, near the river bed, was about 50 ft. The height of the core wall from base to top is 67 ft. The core was constructed of concrete (1:3:6), built up with portable forms, in sections of a length which would force contraction cracks to the joints, where grooves or wells were formed in which pure clay was tamped.

The embankment was formed with earth specially adapted for this type of dam, largely of clay. It was put in, watered and rolled in layers of 6 in. to 12 in. A 10-ton Buffalo-Pitts roller was used for this work.

There are two 30-in. blow-off pipes built through the dam, from intake chambers at the upper toe. These intakes are guarded by screens, and stop-plank grooves are also provided for use if required. At the down-stream toe a valve chamber is built, in which either of the two 30-in. valves may be used in regulating the 30 million gal. flow per day, which must pass the dam, by legal stipulation, for the mills below.

The waste weir or overflow dam is constructed from a bastion at the east end of the diverting dam, extending thence up-stream 1 000 ft., and built of the same section and material as was that at the main dam, previously described; except at the diverting dam no flash boards are to be used.

The water will be impounded in the diverting dam reservoir to Elevation 305, when it will begin to spill over a waste weir into the connecting channel. At the controlling house it may be dammed

by the use of stop-planks, in which case the water may rise to Elevation 310, when it will run over the 1 000-ft. weir, into the waste channel, and down the East Branch of the Croton River. The maximum elevation to which water may be impounded in the diverting reservoir as fixed by law, is Elevation 312 above high water at New York, which elevation equals 315.61 "Croton base."

The principal items of materials used in the construction of the diverting dam were approximately as follows:

Earth excavation, 108 090 cu. yd.; rock excavation, 56 234 cu. yd.; embankment and refilling, 252 000 cu. yd.; Portland cement, 48 384 bbl.; concrete and cyclopean masonry, 37 053 cu. yd.; dimension stone, 776 cu. yd.; paving, 21 904 cu. yd.

Connecting Channel.

From just above the diverting dam, out of the westerly side of the reservoir, an open connecting channel 3 522 ft. long has been excavated and constructed through a depression in the mountain range to the reservoir in the westerly valleys.

The channel begins at a waste weir at El. 305, and then passes through three 17-ft. horseshoe-shaped culverts, beneath the double track of the Harlem Division of the N. Y. C. & H. R. R. R., a distance of about 60 ft. These culverts were built by first carefully tunneling beneath the railroad roadbed without delaying traffic for a moment, and then lining them with concrete, one at a time, until all were completed. From the railroad culverts the channel is cut through rock on a rising grade for about 200 ft. and thence on a falling grade of 2 in 1 000. It is 24 ft. wide at the bottom with slopes of ½ to 1. This rock cut is about 1 000 ft. in length. From that point the channel is through earth, with a maximum depth of about 65 ft., with 1½ to 1 slopes, and a paved invert 15 ft. wide. Twenty-five feet up the slope, at Elevation 315, there is a 10-ft. berm. Above this berm it is on a slope, in earth, of 1½ to 1 to the surface. At the maximum depth of cut, 65 ft., the width at the surface is 230 ft.

The earthy material taken out of this cut was mostly flood drift with large deposits of sand, gravel and clay intermixed, very acceptable for embankment work at the diverting dam, where much of it was used. This formation was so compact, with boulders

FIG. 1 —CONCRETE MIXER AT SOUTH END OF MAIN DAM. CABLEWAY TAKING UP BUCKET OF CONCRETE.

FIG. 2.—CONNECTING CHANNEL. IN EARTH AND ROCK.

admixed, that the wash borings taken before construction proved worthless, the holes encountering boulders so firmly fixed that the boulders were taken for bed rock.

The excavation work was done by Bucyrus 70-ton steam shovels. The material being naturally compact, the teeth of the dipper lasted but a short time, but the material when wet would soften and run like quicksand, even on light slopes. It was necessary, therefore, to lay a 15-in. pipe sub-drain, and keep it open, so as to drain off the water from behind the steam shovel, thus preventing the material from softening and running down, filling the trench, and swamping the shovel.

The sides or slopes to the channel, in earth, were paved with stone taken from the quarry or excavation. They were from 18 to 36 in. deep and as large as the derricks could handle. The paving was laid on 6 in. of broken stone. At the 15 ft. invert, the paving is 36 in. deep; from the invert to the berm (Elevation 315), it decreases from a thickness of 36 in. to 18 in.

Controlling House.—The control of the water coming from the diverting dam, is at four stop-plank openings, each 6-ft. wide, built in the substructure of the controlling house. This controlling house is constructed across the connecting channel in the rock cut, about 200 ft. west of the Harlem Railroad crossing over the channel. By the use of the stop-planks the water can be let through the connecting channel, as desired. The top of the weir at the portal of the connecting channel is at Elevation 305, above which elevation the water may run freely, controlled only by the above stop-planks. The planks are fastened together in 4-ft. sections, and are lifted or lowered by differential pulley blocks, hung from a trolley rail over the openings.

The principal items of material used in the construction of the connecting channel, were approximately as follows:

Earth excavation, 306 392 cu. yd.; rock excavation, 43 093 cu. yd.; paving, dry, 27 717 cu. yd.; Portland cement, 4 403 bbl.; concrete masonry, 4 164 cu. yd.; refilling, 23 246 cu. yd.

New Highways.

Fourteen and one-half miles of new highways were constructed to replace the old roads, which will be submerged when the reservoirs

are filled. These highways were required under the laws of 1883 *et al.* and had to be approved by the Supreme Court. In this "fast age" of automobile travel it is necessary to build roads on light grades and as nearly on a tangent as possible, a task indeed when located on the margin of a reservoir, with the towns' "highway men" standing in the way of the engineer's "foresight," making their selfish demands.

All highways were constructed with a roadway 22 ft. wide, specially surfaced with selected materials, and three-foot ditches on either side in cuts. On embankments the roadway has a width of 28 ft., with a guard rail fencing 25 ft. apart. The right of way provided is generally 50 ft. in width.

Only concrete highway bridges and culverts were built, as the City must forever maintain them.

The directness in route which was required of these highways by a mandate of the Supreme Court, after hearing both the City and the towns' commissioners, made it necessary for heavy construction through deep rock and earth cuttings, and for high embankments, heavily paved to take the wash and wave action of the wind-driven reservoir surface as it rises and falls. There are seven of these embankments, the largest of which is the one across the Middle Branch, which is 100 ft. in height above the old river-bed, 340 ft. wide on the base and 1 200 ft. long. It has two 20-ft. horse-shoe-shape concrete culverts over 330 ft. in length near the river-bed, to conduct the waters from the easterly valleys to the westerly portion of the reservoir behind the main dam. This fill or highway embankment may be considered one of the largest or the largest ever built. (See Plate 73, Fig. 2.)

The entire highway system has been well built, and equal to the State roads, with lighter grades and wider roadbed, but with no macadam. The expense is also greater, but this is due to building through new country, while the State roads are over old routes with few cuts and fills.

The principal items used in connection with the construction of these new highways were approximately as follows:

Earth excavation, 798 000 cu. yd.; rock excavation, 69 000 cu. yd.; Portland cement, 22 000 bbl.; concrete and rubble masonry, 20 000 cu. yd.; paving masonry, laid dry, 35 600 cu. yd.; highway surfacing, 80 000 lin. ft.; post and rail fencing, 110 000 lin. ft.

FIG. 1.—THE DIVERTING DAM, COMPLETED.

FIG. 2.—WASTE-WEIR AND SPILLWAY CHANNEL AT THE DIVERTING DAM; SAME AT MAIN DAM.

PLATE 71.
THE MUNICIPAL ENGINEERS
OF THE CITY OF NEW YORK.
COOK ON CONSTRUCTION OF THE
CROTON FALLS RESERVOIR.

FIG. 1.—CONNECTING CHANNEL TUNNELS UNDER TRACKS OF THE HARLEM RAILROAD.

FIG. 2.—THE CONTROLLING HOUSE ON THE CONNECTING CHANNEL.

Speed of Placing Cyclopean Masonry.

During the month of October, 1908, at the Main Dam, there was a "record made," in the laying of masonry.

During 27 working days there were placed in the dam, 24 266 cu. yd. of cyclopean masonry.

During 30 days (including 3 Sundays), there were placed in the dam 1 666 cu. yd. of concrete facing blocks (720 blocks).

Total masonry of all kinds, 25 932 cu. yd.

On October 16th four gangs were laid off for ½ day owing to the breaking of the button line of the cableway. Eight gangs of 12 men each worked during the month on cyclopean and two gangs of 6 men each worked on the facing blocks

Analysis of Cyclopean Masonry.

14 362 bbls. cement used in 1:3:6 concrete, at 0.96 cu. yd.	=	13 788 cu. yd.
868 bbl. cement used in 1:2 mortar, at 0.48 cu. yd.	=	417 " "
Stone used (balance)	=	10 061 " "
Total cyclopean masonry	=	24 266 cu. yd.

The percentage of stone in cyclopean masonry, 10 061 ÷ 24 266 = 41.4 per cent.

On the entire work, Main Dam, Diverting Dam, Connecting Channel, Highways, etc., there were used over 311 000 bbl. of Portland cement, Giant brand.

CONCLUSION.

In conclusion it may be said, that it was wise to have ordered and built the Croton Falls Reservoir, thus providing additional storage on the Croton Watershed.

It may prove its value at an early day in preventing a water famine, if not in the City of New York, then in the adjoining towns of Westchester County, which are really a part of the greater city, and dependent upon it.

The work has been economically done, and considering the necessary and unforeseen delays, due to the requirements of the law, the negotiations as to the rights of others, together with the late-

ness of the season in which the work was begun and other causes, the work has been quickly done.

AUTHORITY.

The work above described was done by the Aqueduct Commissioners under authority of Chapter 490 of the Laws of 1883 of the State of New York, and amendments thereto, until June 1st, 1910, when the Aqueduct Commission was abolished, and all the powers vested in said Aqueduct Commission, under said Chapter 490, Laws of 1883 and amendments thereto, became vested in the Commissioner of the Department of Water Supply, Gas and Electricity of the City of New York, Henry S. Thompson, Commissioner; I. M. de Varona, Chief Engineer.

CONTRACTOR.

The Contractor for this work was the Croton Falls Construction Company, John F. Cogan, President; Michael Sexton, Vice President; P. J. Cogan, Secretary and Treasurer; P. H. Cogan, Superintendent; Thomas J. Forschner, Manager, and Joseph A. Flynn.

FIG. 1.—REINFORCED CONCRETE HIGHWAY BRIDGE OVER SPILLWAY CHANNEL OF DIVERTING DAM (84 FT. SPAN).

FIG. 2.—REINFORCED CONCRETE HIGHWAY BRIDGE OVER WEST BRANCH, BELOW MAIN DAM (75 FT. SPAN).

FIG. 1.—REINFORCED CONCRETE HIGHWAY BRIDGE (50 FT. SPAN). OVER WEST BRANCH, ROAD NO. 4.

FIG. 2.—EARTH FILL, CARRYING HIGHWAY NO. 9 ACROSS RESERVOIR (100 FT. HIGH AND 349 FT. WIDE ON BASE).

DISCUSSION.

ARTHUR S. TUTTLE, M. M. E. N. Y.—We are all greatly indebted to Mr. Cook for his very complete and interesting paper. The excellent photographs which he has shown of the work have doubtless brought back to your mind a trip to Croton Falls of two years ago, which I believe to have been one of the best attended and most successful inspection trips which the Society has ever made.

There are many present who have been connected with the design and construction of this great work, as well as others who have gained a personal knowledge of its details by reason of a visit to it. The paper is open for discussion and we will be glad to hear from anyone who is prepared to add to what the author has said or who is desirous of further light in any particular.

JOHN F. COGAN.*—Mr. Cook has gone so thoroughly into the matter that there is really nothing for the contractor to say. The contractor, of course, has to do the work under the direction of the engineer. Mr. Cook, I must say, is one of the fairest engineers I have ever worked under in doing City work or in other works. He offered suggestions, and was always willing to pay for the job when it was well done. The work is now practically finished—it will be all finished this week.

C. ELMORE SMITH.†—In regard to the phenomenon of the upper surface of the apparently solid rock cracking up upon being stripped. The overlying material being excavated, the rock surface showed as a smooth, hard gneiss rock, with erosion marks from northwest to southeast, due to prehistoric glacial action. No seams or cracks were apparent and the rock seemed ideal, but almost too smooth a surface for a dam foundation. Had the weather been cool, we would have built upon it after some roughing up, but this rock was uncovered in hot weather, over an area of about 300 ft. by 127 ft. Suddenly, with a "booming and cracking," the rock over a large area, on a previously invisible bed, would lift and arch itself, showing practically horizontal cracks from a maximum of four inches in thickness to a tight, almost imperceptible crack near the edges of the bared rock. These lifted areas started with a feather-edge on their easterly edges and extended westerly, along the axis of the excavation, a distance of 100 feet in some cases, to a hair crack with a thickness of three or four feet. This rock was removed by blasting and barring and wedging, and in some cases the raising or cracking repeated itself a second and even a third time before the rock was covered with masonry.

The only satisfactory explanation I can offer for this action, is the expansion of the rock over the uncovered area, due to the heat

* President, Croton Falls Construction Company.

† Assistant Engineer, Dept. of Water Supply, Gas and Electricity.

of the sun's rays, having never been subjected to any such heat, since its original cooling. I stood on this rock myself, on one occasion, when it "raised" as I have described, over an area of, say, seventy-five by one hundred feet, and I can assure you the sensation was remarkable.

In regard to handling of materials on this work, I would say that the concrete was supplied by the two cableways, and the stone for the cyclopean masonry and the concrete blocks were supplied to the individual derricks by flat cars on spur tracks as described by the author.

The concrete was mixed in two Hains mixers, built on the waste channel bottom, which were supplied with broken stone and sand from piles on this same level, and conveyed to the small supply bins over the mixers, by a conveyor belt working in a timbered tunnel underneath the storage piles. These storage piles were kept full by dump cars on a track along a road line (Road No. 9), running practically parallel with the waste channel and twenty-five feet above it. This track was standard and narrow gage, and the cement storehouse was built on this road along the track so that the standard gage box cars loaded with cement could be brought directly to the dam and unloaded into the storehouse or directly to the mixer, as used, which was the general method, as it saved handling.

The mixers were operated eight hours a day. The work was never delayed a minute for concrete, the mixers never broke down, and the men were kept so busy that it was necessary to relieve them on occasions. The only limit to the output of the mixers was the speed of the cableways, which at the maximum was about 2.7 minutes for an average round trip, with two cubic yards of concrete in each bucket.

The concrete buckets were lowered from the cable to landing platforms or mattresses, made of ties bolted together and placed on the masonry or on the ground, convenient to the derricks, when they were picked up and dumped by the derricks where required. After dumping the empty bucket was returned to the platform and the cyclopean stone placed.

The concrete blocks were set by the same derricks, when not in use for the cyclopean masonry. The aim was to keep the concrete blocks at least one course above the cyclopean masonry, in order to retain the concrete. There were cases, however, when it was expedient to build the cyclopean masonry above the blocks, and in these cases small dams of spalls were built between the stones of the cyclopean masonry in order to retain the concrete, but in no case was this "pyramiding" permitted to a height of over two block courses; generally it was for one course only.

The great saving in time on this work I believe was due to

using the cableways for concrete only, as when eight gangs were placing the cyclopean masonry, the cables were taxed to their full capacity to supply concrete, without using up time to furnish stone and blocks.

The plant was practically all new and was adequate for the work required of it.

Great cerdit is due to the Croton Falls Construction Company for the completeness and thoroughness of the installation, and especially to the manager, Mr. T. J. Forschner, for the efficient and smooth-running organization. The members of this company were gentlemen, who, by their ability, untiring energy and general desire to do all that was required of them by the engineers, earned the respect and good will of all.

ROBERT RIDGWAY, M. M. E. N. Y.—I regret that I have not much to add to the discussion of Mr. Cook's excellent paper. About twenty years ago I was connected with the construction of the dam for Reservoir "M" on the Titicus River, near Purdy Station, a few miles south of the Croton Falls Dam. The Titicus Dam was built of rubble masonry faced with cut stone, not of the cyclopean masonry used in the later dams of the Croton system. In those days the standard practice about here was to use rubble masonry for large dams, though I believe some notable structures abroad, including Vrynwy Dam in Wales, had been constructed of cyclopean masonry.

Six thousand or seven thousand cubic yards of rubble masonry was considered a very good month's work on the Titicus Dam. To show the advance in the art of building dams, in less than twenty years, Mr. Cogan laid something like 25 000 cu. yd. of masonry in one month in the Croton Falls Dam. This, I believe, created a record at the time, and reflected much credit on the contractor's organization of his work.

WALTER CREUZBAUR, M. M. E. N. Y.—This is a very interesting piece of work, which I have seen, however, only in its preliminary stages. At that time I was much interested in the ingenuity and comprehensive methods for handling materials, where the contractor had taken advantage of the natural topography of the surrounding ground in so planning his tracks, trestles, bins, etc., as most conveniently to bring in the great quantities of materials needed for the structures, and the success of these well-planned preliminary works is shown in the progress made in placing concrete, which has been quite remarkable, amounting, as stated, to twenty-five thousand cubic yards in a month. It was only a few years ago, when I was associated with a contracting concern outside of the city service, that we were estimating on a cyclopean masonry dam in another State, where the quarry facilities, sand pits and other features were fully as favorable in location as those found about the Croton Falls

Dam, but we were deterred from competing when we figured that by the time we could get everything under way and turn out concrete we would have to place a thousand yards in every working day for the balance of the contract term to get out without a penalty, and the concern did not bid. If we had Mr. Cogan's example before us it would have been illuminating at that time.

His method of handling concrete with facility is of especial interest, and I think we would like to hear how many mixers were used and a little more about the methods of transportation by the cableway, which seems to have limited the output even in this remarkable progress.

Another point to which a good deal of interest was attached at the time of excavating to bed rock is that of which Mr. Cook has spoken, as to this peculiar rock, which was subject to sudden expansion under the action of the sun, when it flaked off in strips of very considerable thickness.

A MEMBER.—What was the treatment of the face of the concrete in the bridge work and the dam work described?

FREDERICK S. COOK, M. M. E. N. Y.—The concrete in the bridges was cast in forms. After the forms were taken off, the surfaces were rubbed in the ordinary way. In the case of the facing blocks for the dam, the blocks, as described in the paper, were made in forms, building the face against a metal surface prepared with oil, and after removal, the surfaces were rubbed in a similar manner to the bridge surfaces. The process of cleaning down the dam consisted of taking off the concrete that had fallen over the face and fastened itself to the surface.

A MEMBER.—I would like to know from Mr. Cook what length of core wall in the Diverting Dam stood up without showing contraction cracks. He mentioned clay joints at certain distances apart and I would like to know what these distances were.

FREDERICK S. COOK, M. M. E. N. Y.—The length of the core wall is 1 185 ft., with expansion joints and wells placed about 125 ft. apart. In two or three sections cracks occurred. Experience shows us that if we place these joints farther apart than 60 ft., we are tempting a crack between the joints. I believe that 60 ft. is about the maximum length between joints in a core wall, unless it can be covered immediately with earth to keep the temperature of the concrete nearly normal.

GARDNER L. VAN DUSEN, M. M. E. N. Y. (by letter).—Among the many interesting features of this paper, one was of peculiar interest to me, from a geological standpoint. This item was the peculiar action of the gneiss rock in the bed of the excavation for the dam. Mr. Cook states that, upon the exposure of this rock surface by the removal of the earthy material above, there would occur an upheaval,

accompanied by a booming sound and a lamina of rock, running from a feather edge at one side to a thickness of 2 or 3 ft. at the other, would be broken loose from the rock mass at the surface. This action would be repeated when the first loosened material was removed.

During the discussion of the paper this feature was considered, and it was explained as being due to the heating of the hitherto unexposed rock by the summer sun. The idea seemed to prevail that this action of the rock at the dam site was entirely without precedent. It occurs, however, that exactly the same action has taken place in several of the granite quarries in Maine, in cases where the granite has become more or less altered to the laminated structure of gneiss, and where thin strata containing considerable mica occur. It has been generally considered, in these cases, that the rock action was due to lateral pressure, rather than to the heating of the rock surface. At the sides of the quarries the superimposed rock masses exercise enormous pressure, while in the quarry bed all pressure has been removed in the excavation; consequently the strata so uncovered is under enormous stress. The thin strata of micaceous material, being easily cleavable, forms a distinct line of weakness and the upheaval results. This would seem to be a more likely explanation than that of the heating of the surface, especially as the conditions of lateral pressure are exactly similar in the case of the excavation for the Croton Falls Dam.

It occurs to me that the fact of this parallel action of the gneissoid rock in the Maine quarries and the explanation there given may be of interest to some of the members of the Society.

ALFRED D. FLINN, M. M. E. N. Y. (by letter).—The author has assembled much interesting information about the Croton watershed and the second largest reservoir thereon. For purposes of reference, it would be convenient if the description of the contractor's plant could be put into diagrammatic or tabular form instead of being spread through the text. If available, information about the numbers of men employed on different parts of the work, the length of day, and the usual wages for the several principal classes of laborers and mechanics, might profitably be recorded in this connection.

The author mentions the heaving and breaking of the rock in the bottom of a part of the excavation for the main dam, necessitating the removal of a considerable additional quantity. This action seems to have been due not so much to the release of pressure by the removal of the material above this rock as to the large rise of temperature due to long exposure to the summer sun. If the writer remembers correctly, this rock was exposed during the warm season for many weeks. This portion of the rock, as first encountered and prepared for foundation, looked very sound and

remarkably free from seams and cracks, which were so common in other parts of the rock in the immediate vicinity. If the foundation could have been flooded or promptly covered with several feet of masonry, it would seem probable that the heaving might have been prevented.

The writer had a brief connection with this work at its inception. During parts of the years 1904 and 1905, under J. Waldo Smith, as Chief Engineer, he was engaged upon preliminary studies and designs for the Cross River reservoir and one other. The intention was to push to the economical limit the development of the Croton River because of the delay in definitely starting works for additional water supply, as had been recommended in previous years by John R. Freeman and the Burr-Hering-Freeman Commission, successively. The different branches of the Croton watershed were not equally developed, the ratio of storage capacity of the reservoirs to area of watershed being much greater on the Middle and West Branches than on the East Branch; therefore, endeavors were naturally directed toward securing further storage on the East Branch, and to this end surveys were in progress for the so-called Patterson reservoir; this site was not a particularly favorable one for several reasons, and, as the borings did not reveal encouraging conditions for the foundation of the proposed dam, the Patterson site was abandoned, and [following the writer's suggestion] studies were taken up for a reservoir with a dam in the vicinity of Croton Falls. The possibility of constructing a reservoir at this site had been recognized by the engineers who made the early surveys and studies for the Croton development, and they had proposed a small reservoir here. To secure the necessary quantity of water, and, especially, make the basin available for storage of surplus waters from the East Branch, a diverting dam and reservoir, near Dean's Corners, with a connecting channel to the main reservoir, were proposed. When, at the end of July, 1905, the writer left the Aqueduct Commissioners to accept appointment with the Board of Water Supply, the main features of design and specifications for the Croton Falls reservoir had been developed in the office, and surveys and borings were well advanced, but the details remained to be worked out. Under Walter H. Sears, as Chief Engineer, the designs and specifications were completed by George A. Taber, Assistant Engineer, and Edward L. Walker, General Inspector.

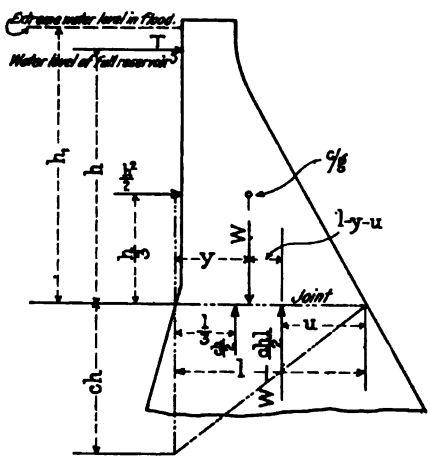
As nothing is said in the paper about the design of the main dam, the following formulas, which were arranged by the writer for this purpose, may be of interest. They were adapted from formulas developed in connection with the design of the Wachusett dam, of the Boston Metropolitan Water-Works, and the Boonton dam, for the water supply of Jersey City. The formulas for the

Boonton dam were arranged, if the writer remembers correctly, by William B. Fuller.

With the completion of the Croton Falls reservoir, it is the writer's opinion that the development of the Croton watershed by the building of impounding reservoirs has reached the economical limit. In view of the fact that the work on the Catskill additional water supply is now well advanced, it is not necessary to carry the development of the Croton watershed beyond the economical limit, although such a course might have been advisable a few years ago. Indeed, with the existing reservoirs, when their storage is largely depleted, so long periods elapse before they are filled again that offensive vegetation grows on the margins of the reservoirs below high-water level and militates against the quality of the water.

CROSS RIVER AND CROTON FALLS DAMS.

METHODS, FORMULAS AND ASSUMPTIONS FOR DESIGNING THE CROSS-SECTIONS.



TYPICAL SECTION

Symbols and Units.

W = weight of masonry above joint;

T = thrust of ice at water surface, considered horizontal;

$\frac{h^2}{2}$ = horizontal thrust due to static pressure of water against the up-stream face of the dam;

$\frac{h_1^2}{2}$ = ditto for water at flood level;

ch = intensity of pressure of water vertically upward at up-stream side of joint; it is considered to decrease uniformly to zero at the down-stream side.

Unit of weights and forces is the weight of 1 cu. ft. of water (62.5 lb.);
Lengths in feet;
Weight of masonry is taken as $2\frac{1}{2}$ times weight of water (156.25 lb. per cu. ft.).

Formulas Relating to Stability of Dam.

Horizontal plane joints assumed at various convenient elevations, or distances below top of dam, for purposes of computation.

Moments of forces taken about intersection of line of action of W with joint, the forces being represented by their resultants and considered to act in the same vertical plane.

A cross-sectional slice of the dam 1 ft. thick is used for computation and so the forces are those acting upon one linear foot of the dam.

Begin with assumed profiles and modify, if necessary.

The following formulas determine the position, under various assumptions, of the intersection of the resultant of the forces acting on the dam with the joint in question. In other words they determined the position of the "line of pressure."

General Equations for Stability against Overturning.

$$Th + \frac{h^3}{6} + \frac{chly}{2} - \frac{chl^2}{6} - (l\text{-}y\text{-}u)\left(W - \frac{chl}{2}\right) = 0.$$

1st Case.—Water pressure only, water at full reservoir level, $T = 0$, $c = 0$.

$$l\text{-}y\text{-}u = \frac{h^3}{6\,W} \text{ or } \frac{h^2}{6\,\frac{W}{h}}.$$

2d Case.—Water pressure and ice pressure, water at full reservoir level, $c = 0$.

$$l\text{-}y\text{-}u = \frac{h}{6\,W}(6\,T + h^2) \text{ or } \frac{6\,T + h^2}{6\,\frac{W}{h}}.$$

3d Case.—Water pressure and upward pressure beneath joint, $T = 0$.

$$l\text{-}y\text{-}u = \frac{h^2 + cl\,(3\,y\text{-}l)}{6\,\frac{W}{h} - 3\,cl}.$$

4th Case.—Water pressure, ice pressure and upward pressure.

$$l\text{-}y\text{-}u = \frac{6\,T + h^2 + cl\,(3\,y\text{-}l)}{6\,\frac{W}{h} - 3\,cl}.$$

5th Case.—Water pressure only, water at flood level, $T = 0$, $c = 0$, $h = h_1$.

$$l\text{-}y\text{-}u = \frac{h_1^3}{6\,W} \text{ or } \frac{h_1^2}{6\,\frac{W}{h_1}}.$$

Sample of a Convenient Arrangement of Computations.

CASE 5.

El. of Joint.	W	h_1	h_1^2	$6\frac{W}{h_1}$	l	y	$l\text{-}y\text{-}u$		u	
							1			

For Cross River Dam, assume $T = 24\,000$ pounds $= 384$ water units.

For Croton Falls Dam, assume $T = 30\,000$ pounds $= 480$ water units.

For both, assume $c = \frac{3}{4}$.

Croton Falls dam will be the more important and will impound a very much larger quantity of water; there are several dams above its site; the configuration of the reservoir makes ice thrusts more probable; hence it should be stronger.

Arrangement of Computations.

Tabulate the computations made with the formulas above as indicated below.

(NAME OF DAM.) TRIAL SECTION NO..... STABILITY AGAINST OVERTURNING.

CASES 1 TO 4.

El. of Joint.	W	h	h^2	$6\frac{W}{h}$	l	y	cl	$3\,y\text{-}l$	$l\text{-}y\text{-}u$				u			
									1	2	3	4	1	2	3	4

Compute the location of the center of gravity of the portion of the dam above each assumed joint by moments, to determine y, and check by cutting the section out of cardboard, suspending it from 2 or 3 points successively, drawing the plumb lines and finding the intersection.

Formulas for Intensity of Pressure at Faces of Dam.

Resolve the resultant of all the forces assumed to act upon the dam in any given case as stated above into a vertical and a horizontal component. Consider successively assumed portions of the dams above convenient horizontal joints.

Regard the horizontal component as uniformly distributed over the whole joint.

Regard the vertical component as distributed in accordance with the trapezoidal law—a straight line distribution. The intensities of the pressure at the face of the joint nearer to the resultant will, on this basis, be given by the following formulas:

Let p = intensity of pressure at face of joint in tons of 2 000 lb. per sq. ft., *i. e.*, the maximum intensity;

v = distance from nearer face of joint to point of application of resultant.

Other symbols as before.

1st Case.—$v > \frac{l}{3}$.

$$p = \frac{W}{16\,l}\left(2 - \frac{3\,v}{l}\right).$$

2d Case.—$v = \frac{l}{3}$.

$$p = \frac{W}{16\,l}.$$

3d Case.—$v < \frac{l}{3}$.

$$p = \frac{W}{48\,v}.$$

GEORGE A. TABER, M. M. E. N. Y. (by letter).—The work described in this paper is one with which the writer has been connected for many years, not so much with the work of construction in the field, as with the details of design and general problems of administration in the main office.

When the writer first became associated with this work, in the latter part of 1905, the main features of the undertaking had, in a general way, been decided upon, as stated by Mr. Flinn in his discussion. There remained, however, the preparation of the contract drawings in detail, the contract and the specifications, and after the contract was let, the detailed construction drawings as the work progressed, all of which came under the supervision of the writer, who reported directly to Walter H. Sears, Chief Engineer of the Aqueduct Commissioners.

As noted by the author, the cross-section of the Croton Falls Dam is heavier than the Cross River. The top width is the same

for both dams (23 ft.) but the down-stream face of the Croton Falls curves downwards with a radius of 79 ft., while that of the Cross River has a radius of 96 ft. Both curves are joined by a tangent on a batter of 0.56 to 1, making the Croton Falls Dam about 2½ ft. thicker than the Cross River for practically its entire height. This extra thickness was largely necessary on account of the Croton Falls Dam being situated below several other large dams on the watershed, the failure of any one of which would subject the Croton Falls Dam to a heavier flood than could ever come on the Cross River, which is not so situated. The Croton Falls Dam is also provided with 9 2½ by 5 ft. sluice gates which pass the water through the dam, while the Cross River has but 4 gates of the same size.

The specifications and contract drawings required that the steps of the spillway at both the main and diverting dams be made of block stone, "which is to be especially sound, hard and compact granite." The writer believes that the substitution of reinforced concrete for granite blocks in this work will prove to be an unwise modification of the original designs, as these steps will have to stand the force not only of the waste water, but also of the débris and ice which may be carried over them in times of flood.

There is one feature of the work to which the author alluded which could well be enlarged upon, and that is in regard to the change in design of the connecting channel. The proposed location of this channel was laid out on the ground, a line of wash borings made by the field division, and the results of these turned in to the designing division, as a basis for the design of the channel. These borings were made with all due care, and showed that rock existed over a greater portion of the line from 10 to 20 ft. below the surface. Near the center of the line, for a length of about 600 ft., the maximum cut varied from 50 to 60 ft., of which, as indicated by the wash borings, the greater portion was rock. The section of channel was, therefore, designed 30 ft. wide on the bottom, with side slopes in rock from ¼ to 1, and, from the top of the rock, slopes of 1½ to 1 in earth. When this section was excavated it was found that there was no rock at all at this location, and the proposed cross-section of the channel had therefore to be modified to suit an earth cut 60 ft. in depth. It was made 15 ft. wide on the bottom, with side slopes of 1½ to 1, making a very wide channel, and giving a large amount of earth excavation and slope paving that was not anticipated. The material was found to be of glacial deposit, and filled with a great number of excessively large boulders, which were struck by the wash borings and thought to be ledge rock. This forcibly illustrates the lack of definite information obtained from wash borings, and shows that for work of great importance, diamond-drill holes should always

be put into the rock a sufficient depth to make sure that it is really ledge rock, and not merely a boulder or some large fragment.

The writer wishes to record his appreciation of the services of Edward L. Walker, M. M. E. N. Y., who, under the direction of the writer, had immediate charge of the drafting room, where the designs, specifications, and details for this work were made; also, to record the names of Alfred S. Burgess, M. M. E. N. Y., to whom many detailed problems of design were entrusted; of Albion W. Falk, Architectural Draftsman, who was responsible for many of the architectural features of the work, and of Jean P. Genthon, M. M. E. N. Y., whose long experience and familiarity with the details of the work of the Aqueduct Commissioners, and especially with the real estate "taking" maps, made his services of especial value.

C. ELMORE SMITH (by letter).—Mr. Van Dusen's interesting discussion, it seems to me, presents a somewhat different condition, in regard to the cracking up or raising of the rock, than that encountered at Croton Falls, where it was the surface of the rock thus affected, and not rock at a considerable depth, after the overlying granite had been removed, as in the case of the Marine quarries. The condition of which Mr. Van Dusen speaks, seems more nearly like the "popping" of the rock in the deep shafts of the Storm King crossing for the Catskill Aqueduct.

The rock surface over the portion of the foundation of the Croton Falls Dam, which exhibited this peculiar, but not startling or unheard of condition, had only been relieved of the pressure due to its overlying strata of earth, to a depth generally, of not over 40 ft. The temperature of the water coming from springs at the sides of the excavation was about 50°, and this was probably somewhere near that of the rock before it was uncovered. After being bared and exposed to the rays of the summer sun, the temperature rose in cases to at least 125°, a difference of 75°, which with the consequent expansion over this heated portion, reacting against the covered cool rock at the sides of the excavation, seemed to us to account perfectly for the lifting on the hitherto tight seams or beds, as this was obviously the only direction in which this force could exert itself freely.

FREDERICK S. COOK, M. M. E. N. Y.—The explanation offered by Mr. Van Dusen of the "snap and boom" which occurred in the excavation for Croton Falls Dam, is quite interesting, but I am yet of the opinion that it occurred for the reasons given, the change in temperature from 50 to 125°. There was no "superimposed rock masses" exercising "enormous pressure," but only the earthy material, about 40 ft. deep (2¼ tons per sq. ft.), had been removed from the surface of the rock in question.

Careful observations showed us that there was a rise in temper-

ature of over 75°, thus bringing about an expansion in the surface lamina, to an extent sufficient to open vertical cracks and a consequent upheaval or buckling.

The discussion furnished by Mr. Flinn, adds much to the value of the paper. In regard to the breaking of the surface rock in the bottom of the earth excavation for the Main Dam, Mr. Flinn observes: "if the foundation could have been flooded or promptly covered with several feet of masonry, it would seem probable that the heaving might have been prevented." As Mr. Flinn states, the rock did appear remarkably firm, but it is evident from what transpired that there were seams. Under the then existing circumstances it would not have been practicable to flood the excavation, as we were endeavoring to remove all dirt, etc., in preparing the rock surface, which seemed acceptable, for the masonry, which was to have been placed as soon as the "bottom" had been thoroughly washed with clean water, using at times therewith wire brushes, until acceptable. On the 15th of April the first two facing blocks were set; shortly after this the upheaval referred to occurred.

Owing to the brevity of the time allowed in preparing the paper, I omitted to note the number of men employed, the number of hours in working day and the rates of pay. Briefly it may be recorded as follows: The Labor Law and the Contract required that eight hours within the twenty-four should constitute a day. This was rigidly enforced and carried out; at times two shifts were employed, but not continuously. The number of men employed during the year 1909 was from 600 to 1 500; 1 000 being a fair average.

The men were paid (common labor) $1.50, $1.75 and $2 per day. The latter rates applied to some of the better class. Masons and carpenters were paid $2.50 to $4.00 per day; foremen, engineers ("Dinkey Skinners") $3.00 and $3.50 per day; division foremen, superintendents and time keepers were paid by the month.

Mr. Taber in his discussion adds to the history of the Croton Falls Reservoir work.

In regard to the change from granite to reinforced concrete in the steps of the waste weir or spillways, I cannot agree with Mr. Taber, for I am of the opinion, in the light of modern practice, and the records of tests made of concrete as compared with granite, that Chief Engineer Walter H. Sears, concurred in by Prof. W. H. Burr, of this work, made no mistake in ordering the change referred to. I also believe that there is no reason to expect, hereafter, "great floods" which will carry débris and ice over these steps. The belief of eminent engineers, as expressed by them, is that with the Croton Falls Reservoir finished, there is no necessity of building more impounding reservoirs, to hold back the flood waters, as the development of the Croton watershed has reached its economical limit.

THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.

ADDRESS OF ARTHUR S. TUTTLE, PRESIDENT OF THE MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.

PRESENTED AT THE ANNUAL MEETING OF THE SOCIETY ON JANUARY 25TH, 1911.

The success of any organization depends upon the existence of a need for it and upon a united effort on the part of those having its welfare at heart. Such success cannot be measured in terms of revenue or in the number of names carried on the rolls, nor can it be deemed of a permanent character if the growth is not healthy and steady and unless its object is kept steadfastly in mind.

We can certainly congratulate ourselves upon the possession of the essentials for placing our Society upon a footing which must survive. From year to year we fail to detect any marked change in our affairs, but as we compare the present with the earlier days we are strongly impressed with a feeling that we have gradually become a cohesive body with established policies and traditionary customs.

It is a matter of frequent comment on the part of those connected with other societies working along lines similar to ours, that the attendance at the regular meetings represents an unusually large proportion of the membership. It is not so well known, and perhaps not even to our members, that back of this there lies a remarkable attendance record on the part of your Board of Directors, and this irrespective of weather and personal convenience. There have sometimes been radical differences of opinion concerning the treatment of matters brought up for consideration, but at no time have these differences concerned the objects we aim to accomplish, nor have they left any trace of discord or been of a character other than such as would stimulate greater interest in our work.

The original determination to put our profession and the City first and our individual interests last, is, to my mind, the secret of

our growth and present strength. Our work has been done quietly and unobtrusively, but its value has come to be generally recognized as measuring up to a high standard.

Of late years and during a period about co-temporaneous with our life, there has been growing up a belief that the engineer is superseding the lawyer and the elected office-holder in exercising the most important functions of our municipal government. In these days when municipalities are directing their attention to improvements of a gigantic character, wholly undreamed of in years gone by and dependent for their success upon the engineering skill with which they are carried out, the explanation of the new prominence of the engineer becomes easy. That he is now frequently called upon to occupy administrative offices is undoubtedly due to the training which comes to him in carrying out these great undertakings, and for which his education has already given him special qualifications.

It must be conceded that the engineer in the past has generally devoted himself too freely to the technical questions confronting him and too little to the more practical ones, and that in municipal work his thoughts have been more apt to confine themselves to the details of the particular work in hand rather than to the broader view of its relation to other municipal activities. If the profession is to continue to hold the enviable position which it has now attained, it is important that a broad outlook should be cultivated, and that the work done under engineering direction should be carried out with full recognition of the important parts which men of other professions or training must and should exercise in directing city affairs. If engineering service stands out prominently as a factor in city building it should be for the reason that its sphere is, at least for the time being, the most important one and not by reason of undue modesty or self-seeking on the part of those engaged in it. So long as these principles are adhered to we may regard our advance with supreme satisfaction, but should the time arrive when they are forgotten, the downfall of the engineer as an important factor in city government will be assured.

In the cultivation of an appreciation of the extent of and necessary co-operation in carrying out the work undertaken by our City, I believe that this Society will find the richest field for the produc-

tion of results for the common good. It is to this line we have hewn, and it is the course which clearly appears to be the right one for the future.

We now enjoy the distinction of being the only engineering society which devotes its whole time and effort to the consideration of the engineering problems of one city, but as time goes on it needs no prophet to forecast that the good work done here will lead to the formation of similar organizations in other cities.

It was with the evident intent of keeping our attention directed to the past history of this organization and to the close relations which certain lines of municipal work bear to each other, notwithstanding that they are under totally different jurisdictions, and so that we might more intelligently direct our future course, that an annual review is required from your President concerning our own progress as a Society and the engineering work carried out within the City limits.

Meetings.

The attendance at our meetings has ranged from 71 as a mimimum to a maximum of 177, averaging 136. The papers presented during the year have dealt with bridge design and construction, waterfront improvement, city planning, tunneling, dams, highway maintenance, and the disposal of sewage. These subjects have covered a wide field and have developed a large amount of interest. We may congratulate ourselves on the value of these contributions to engineering literature and on the extended and extremely interesting discussion of each. If it were practicable to furnish members with advance copies of papers there can be no doubt but that the discussion would be even at greater length and would be participated in by many who now fail to express their views. It is hoped in the near future to, at least in part, secure this result through the medium of the engineering journals. The Publication Committee has already arranged for four papers to be read in 1911, all of which are up to the high standard heretofore maintained.

Membership.

During the past year there has been practically no change in our numerical strength. Your Board of Directors has maintained

its previous policy of dropping men from the rolls who continue to remain indifferent to their financial obligation to the Society, and our ranks have also been somewhat depleted by reason of the curtailing of the work of several branches of the City government. These losses have been approximately balanced by the admission of new members, the total enrollment at the close of the year being 513. With activity about to be resumed on the part of the Public Service Commission in the way of subway construction, the field for reinforcing our membership will be expanded. We have also good reason to believe that other engineers in the City service who have not yet allied themselves with us will do so in the near future.

Finances.

The 1910 budget was the first one set up for an entire year's guidance, and the experience gained in thus formulating our finances along orderly lines has led to the adoption of the same system for next year. From the report of the Finance Committee it appears that while the expenditures for 1910 have closely approximated the budgetary amount, the revenues have been several hundred dollars less than estimated, the latter discrepancy being due in part to the non-payment of dues and in part to a lesser net income from the publication than was anticipated. The financial reports also show that the disbursements have slightly exceeded the receipts, but that this apparent deficit is more than offset by the much greater advance payment made in anticipation of the publication next year of the volume containing the 1910 proceedings as compared with the similar advance payments made during 1909, the actual gain being about $350. The 1911 budget as planned should result in a surplus at least as large as for the past year.

It was originally proposed to fix the dues of this Society at the minimum rate required for meeting current expenses, so that its advantages could be availed of by all grades in the engineering service. As a result of the saving effected during the time when the Society had less expensive quarters than those now occupied, it was possible to accumulate a sufficient fund to justify an investment in revenue producing City bonds. The books show a continuous increase in the value of our property at the end of each year, but other than during the period of reference it has not been found

practicable to increase the actual cash on hand. I do not know that there is any substantial argument to be offered in favor of the accumulation of a surplus, but at the same time I would point out that if funds were available the Society might at some future date be justified in undertaking research work and in adding to its usefulness in other ways. It has been hoped that our publication would prove to be self-supporting through the advertising revenue, but this hope has proved to be more and more disappointing as time goes on. From year to year your directors have had financial problems to deal with in meeting this expense and usually with the result of materially modifying the previously planned financial arrangements.

Quarters.

The commodious and attractive quarters of the Society, to which members have access at all times, are not used to an appreciable extent, and were it not for the need of housing the library, the value of which is continually growing, it is doubtful if the expense of maintaining them would be justified. It is probable that the location of our rooms with reference to the office building section is responsible for the non-use during the day, and that evening attendance will have to be stimulated by special attractions of such a character as to result in our members "forming the habit."

Inspections.

Six inspection trips were made during the year, these covering a variety of works of great interest, including the new Madison Avenue bridge, the Brooklyn Navy Yard, the works of the General Electric Company, the Albany filtration plant, the canal locks at Waterford, the new open cut of the Erie Railroad at Bergen Hill, the plant of the College of the City of New York, the New Municipal Building, and the Centre Street subway. The visit to Albany, Waterford and Schenectady formed a radical departure from what has heretofore been the custom, as it involved an absence of from two to three days, advantage having been taken of the Decoration Day holiday. The success of this trip should lead to others of a similar nature, affording an opportunity to examine municipal improvements in progress in other cities.

Special Committees.

The standing committees on Uniform Highway Practice, and on Rainfall and Run-Off, appointed a few years ago, have been continued. Owing to the work done by an engineering committee appointed by the Board of Estimate and Apportionment to devise standard paving specifications, the former committee of our Society has had no occasion to continue its independent work.

Special committees have also been appointed in the matter of securing suitable quarters in the new Municipal Building and the enactment of proper legislation governing the licensing of engineers to practice in this State. The former committee has been clothed with power to represent the Society at the proper time and to negotiate for the use of a portion of the surplus space in the building of reference, which will be located at the great center of municipal activity.

During the past year a measure was introduced in the Legislature providing for the issue of a license to engineers, and prohibiting the practice of engineering by those not receiving a State license. The bill was made the subject of very serious consideration on the part of your Board of Directors, and in the report submitted to you by their committee substantial argument was offered against a number of its important features. As a result of this report you unanimously directed that active measures be taken to prevent the passage of the bill and it is probable that its failure was in no small measure due to your views. The committee has since actively continued the work previously begun and has endorsed and has recommended to you for adoption a bill drafted by the Board of Direction of the American Society of Civil Engineers, which, it is believed, adequately provides in a reasonable way for State recognition of engineering as a profession.

Annual Dinner.

This function has been more and more recognized each year as an important feature of our organization life, and we have succeeded in attracting to it not only an attendance almost equivalent to our entire membership, but also a group of speakers second to none who appear at similar events. The good-fellowship and enthusiasm, and

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There is one feature of the work to which the author alluded which could well be enlarged upon, and that is in regard to the change in design of the connecting channel. The proposed location of this channel was laid out on the ground, a line of wash borings made by the field division, and the results of these turned in to the designing division, as a basis for the design of the channel. These borings were made with all due care, and showed that rock existed over a greater portion of the line from 10 to 20 ft. below the surface. Near the center of the line, for a length of about 600 ft., the maximum cut varied from 50 to 60 ft., of which, as indicated by the wash borings, the greater portion was rock. The section of channel was, therefore, designed 30 ft. wide on the bottom, with side slopes in rock from ¼ to 1, and, from the top of the rock, slopes of 1½ to 1 in earth. When this section was excavated it was found that there was no rock at all at this location, and the proposed cross-section of the channel had therefore to be modified to suit an earth cut 60 ft. in depth. It was made 15 ft. wide on the bottom, with side slopes of 1½ to 1, making a very wide channel, and giving a large amount of earth excavation and slope paving that was not anticipated. The material was found to be of glacial deposit, and filled with a great number of excessively large boulders, which were struck by the wash borings and thought to be ledge rock. This forcibly illustrates the lack of definite information obtained from wash borings, and shows that for work of great importance, diamond-drill holes should always

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in feet. This work is comparable with the best precise leveling done in this or in any other country, and when the work is consummated, the City of New York will have a comprehensive system of primary bench marks covering each borough, all referred to the one universal datum plane adopted by the engineering departments of the national government, mean sea level at Sandy Hook.

DEPARTMENT OF TAXES AND ASSESSMENTS.

Maps have been prepared during the year showing the 1910 assessed value per front foot of normal lots having a depth of 100 ft., following a plan similar to the one inaugurated last year. These maps relate to every block of frontage within the city limits and have been published as supplements to the *City Record.*

Twenty-four volumes of new tentative tax maps have also been made for the 4th Ward of the Borough of Queens, this being identical with the former town of Jamaica with an area of 38 800 acres.

The records show that the assessed valuation of taxable property for the year 1910 is $7 416 838 299, while that of property exempt from taxation is $1 359 014 139, making a total valuation of $8 775 852 438.

PUBLIC SERVICE COMMISSION.

In addition to the construction work which has been actively carried on during the year and is briefly described in this review, a very large amount of work has been done by the designing department, this including the preparation of the drawings required for work in progress and the complete designs for the Tri-Borough Route. Studies have also been made for the proposed new rapid transit routes, these including the Utica Avenue and Eastern Parkway lines, the extension of Contract No. 2 on Flatbush Avenue, and the Staten Island connection with the Fourth Avenue subway by way of the Narrows; for the proposed Seventh Avenue and Fifty-ninth Street crosstown line; for the elimination of the New York Central tracks from the roadway of Eleventh Avenue and other streets; and for the third-tracking of the Second, Third, and Ninth Avenue elevated lines and the building of various extensions to these lines in the Bronx. The latter work included the extension

of the Ninth Avenue elevated across the Harlem River into the Bronx, and up Jerome Avenue to Woodlawn Cemetery, there connecting with the proposed Tri-Borough Route; the extension of the Third Avenue Elevated, leaving the present line just north of Pelham Road and connecting with the proposed White Plains Road elevated by way of Webster Avenue and Gun Hill Road; and a proposed connection between the Second Avenue elevated and the Queensboro Bridge. This proposition also includes the transfer of the Steinway Tunnel to the City.

BROOKLYN AND MANHATTAN LOOP LINES. (MANHATTAN SECTION.)

Construction work on the Manhattan sections has continued, with the exception of section 9-0-1. Sections 9-0-2, 9-0-3 and 9-0-5 have been completed, and Section 9-0-4 is about 99% completed. Work on Section 9-0-1 was stopped in May, 1908, on account of interference with the foundations for the proposed new Municipal Building; the necessary changes in the subway plans have now been made, upon the approval of which by the Board of Estimate, work is to be resumed.

The total estimated value of the work done by the several contractors up to the close of the year, is approximately $8 435 000.

PLATFORM EXTENSIONS. (MANHATTAN, BROOKLYN AND THE BRONX.)

The work of extending the station platforms in order to accommodate ten-car express and six-car local trains was begun this year and has continued steadily, although, owing to the conditions under which the work is necessarily done, very rapid progress cannot be made.

It is estimated that about 85% of the work has been completed, at a cost of about $1 090 000.

ADDITIONAL STATION AT WEST ONE HUNDRED AND NINETY-FIRST STREET, AND ADDITIONAL ELEVATOR SHAFT AT WEST ONE HUNDRED AND EIGHTY-FIRST STREET STATION.

At West One Hundred and Ninety-first Street, the work includes the sinking of a shaft (28 ft. by 31 ft. in cross-section, and 183 ft. deep), the construction of a new (tunneled) station 480 ft. in length, the connection of the two by means of a tunneled drift,

and the installation of elevators and a stairway in the shaft. Work on the shaft was begun in July, 1909; it is now approximately 90% completed, at a cost of about $389 380.

At West One Hundred and Eighty-first Street, the work includes the sinking of a shaft (55 ft. by 14 ft. in cross-section, and 142 ft. deep), a tunneled drift to connect with the West One Hundred and Eighty-first Street station, and the installation of elevators and a stairway in the shaft. The whole work is approximately 90% complete, at a cost of about $142 141.

The work is interesting and difficult, particularly at West One Hundred and Ninety-first Street, where the rock is "heavy," and it was necessary to proceed with great caution in tunneling for the station, so as to interfere as little as possible with the regular running of the subway trains.

Zoological Park Station.

In February work was begun on the permanent terminal station at East One Hundred and Eighty-first Street, to take the place of the temporary one previously built at East One Hundred and Eightieth Street. In connection with this station a recreation room is provided for the subway employees. It was opened for the operation of trains on October 28th, and is now very nearly completed.

While a portion of the structure contemplated in the original contract was omitted, this was more than offset by the increase due to provision for a third track and a much larger station, the price agreed upon for this increase being $31 500.

Fourth Avenue Subway, Brooklyn.

The portion now under contract, about four miles in length, extends from Manhattan Bridge through Flatbush Avenue Extension, Fulton Street, Ashland Place, and Fourth Avenue to Forty-third Street. It was let in six sections to four different contractors, at an aggregate price of $15 886 381.20, this including $991 617.55 for pipe galleries. The excavation is entirely in sand, or sand and gravel, with occasional boulders. Along Fulton Street and Ashland Place, where the line passes under private property, the necessary easements have been secured and the buildings in the way of the work have been demolished. In the Flatbush Avenue Extension open-cut

excavation is permitted, but elsewhere contractors are required to keep the excavation to a great extent covered over. The various methods adopted for the underpinning of buildings are an interesting feature of the work.

Work was begun on the several sections on dates varying from late in the year 1909 to March, 1910. In terms of contract value, the amount of work done at the end of the year is approximately 28% of the whole, or about $4 477 000.

Miscellaneous.

Several pieces of work of minor importance were begun or completed during the year.

Among these are the installation of an escalator at East One Hundred and Seventy-seventh Street station, which was put in operation in June; the widening of the easterly stairway at West One Hundred and Fifty-seventh Street and Broadway station which is now practically complete; and four additional entrances to the Atlantic Avenue station, Brooklyn, on which the work is well advanced.

In this connection, it may be stated that arrangements have been made to provide additional entrances at the Fulton Street, East Fourteenth Street, Grand Central, West One Hundred and Third Street, West One Hundred and Tenth Street and Broadway stations, in Manhattan, and at East One Hundred and Forty-ninth Street and Third Avenue station in the Bronx, and that construction will probably be begun shortly. An additional entrance (shaft and elevator) is also being considered for the West One Hundred and Sixty-eighth Street and Broadway station.

Work Done by the Interborough Rapid Transit Company.

With the approval of the Commission, but without cost to the City, the Interborough Company has undertaken the construction of an additional station at Intervale Avenue; the installation of an automatic sprinkler equipment for the Broadway Storage Yard, between West One Hundred and Thirty-ninth Street and West One Hundred and Forty-fourth Street; and the construction of a large Storage Yard just west of Broadway at West Two Hundred and Fortieth Street.

The Intervale Avenue station was begun in December, 1909, and completed in July, 1910; it was opened to the public on April 30th.

The automatic sprinkler equipment begun in December, 1909, was completed in May. The system of piping within the yard comprises about 2 100 ft. of 6-in. pipe, 1 300 ft. of 4-in. pipe, 12 000 ft. of sprinkler pipe and 1 500 sprinkler heads.

The West Two Hundred and Fortieth Street storage yard was begun in November, 1909, and while the work is not completed, good progress has been made. The yard includes train sheds and repair shop with brick walls and reinforced concrete roof.

Arbitration.

The question of the contractor's claims (amounting to $6 198 514.92) in connection with Contract No. 1, which has been before a Board of Arbitrators since March, 1908, required the services of a considerable number of the engineers who were familiar with the work during construction. In July last the proceedings had reached a point where it was evident that all the preparatory work had been done and that it would then be necessary to explain minutely to the Board of Arbitrators all the details of the very great number of items and sub-items, each as was said "amounting to a lawsuit in itself," and that the consequent examination of witnesses on the stand would not only take probably two years or more of time but would also be very expensive. To avoid this expenditure of time and money, it was arranged to endeavor to reach a conclusion, which could be presented to the Board of Arbitrators, by means of a conference of the engineers and lawyers from each side. Such a conference was held in August, and lasted about ten days, one of the commissioners from the Public Service Commission and an Assistant Corporation Counsel also being present. An agreement was reached, except on three or four points, which were quickly decided before the Arbitrators. This agreement has been approved by the Interborough Company and by the Public Service Commission, and will probably shortly be forwarded to the Board of Estimate and Apportionment for approval. It provides for an allowance to the contractor of $1 684 109.33 for extra work, this representing the net total after allowing the City $630 510.99 on account of counterclaims, omissions, etc., and in excess of

$35 000 000, the original contract price. It might be noted that the protocol on which the settlement was based provided that any sum which might be allowed by the City and accepted by the contractor should be reserved for the construction of new subways, or for additions hereafter made to existing subways or new equipment not provided for as extras under existing contracts.

Tri-Borough Route.

The Commission advertised for proposals by private capital for the construction, equipment and operation of the so-called Tri-Borough Route, naming October 20th as the day for the opening of bids. This work called for the construction of 37.69 miles of structure with 121.5 miles of single-track, and for the equipment and operation of 47.17 miles of structure with 144 miles of single-track, the Loop Line and Fourth Avenue Subway now under construction being added.

No formal bids were received, although as a subsequent date propositions were presented from the Hudson and Manhattan Railroad Company, Mr. William G. McAdoo, President, and from the Interborough Rapid Transit Company, Mr. Theodore P. Shonts, President. Both propositions modified the route planned by the Commission and the former one was withdrawn on December 15th last. The latter proposition has been tentatively recommended to the Board of Estimate and Apportionment for approval. At the close of the year its terms were under consideration by that body. It involves a considerable portion of the Tri-Borough Route, together with the one proposed in Seventh Avenue, and is based on the contribution of $53 000 000 by the City toward the cost of construction, while the remaining expense, estimated to aggregate about $75 000 000, including construction and equipment, is to be met by the company. The proposition also includes the completion and operation of the Steinway Tunnel and the third-tracking of the elevated routes in Manhattan and the Bronx at an additional expense to the company of about $32 000 000.

The Commission also advertised for bids for the construction of a portion of the Tri-Borough Route at municipal expense, the portion advertised being the Lexington Avenue Route in Manhattan and the subway portion thereof in the Bronx, the Canal Street route

in Manhattan, and the Brooklyn and Manhattan Loop Lines in Brooklyn, leaving the elevated portions of the system in the Bronx, and the extensions of the Fourth Avenue Subway from Forty-third Street and Fourth Avenue to Fort Hamilton and to Coney Island for a later date. This called for the construction of 16.37 miles of structure, requiring 51.4 miles of single track.

Bids were opened October 27th. There were twenty-one sections advertised, and seventy-seven bids were received, including bids on the alternative plans advertised for the Harlem River section (14).

The number of sections and the aggregate of the lowest bids for each route are as follows:

Route.	Number of sections.	Aggregate of lowest bids.
5 (Lexington Avenue)	16	$59 746 656.59
20 (Canal Street)	2	13 766 554.40
9 (Broadway-Lafayette Avenue)	3	11 924 359.12
Total	21	$85 437 570.11

These bids are for construction only and do not include tracks or station finish.

BOARD OF WATER SUPPLY.

During 1910 construction work was prosecuted actively on 27 main contracts for the Ashokan impounding, the Kensico storage and the Hill View equalizing reservoirs, and the 92 connecting miles of Catskill Aqueduct north of New York City. Three of these contracts, amounting to $4 875 000, were awarded during the year, making the aggregate amount of contracts in force nearly $70 000 000, upon which over $15 000 000 was earned during the year, making a total of $25 000 000 to date.

An American record for hard rock tunneling was made in excavating the Wallkill pressure tunnel in the month of September. At a depth of 340 ft. this circular tunnel, about 17 ft. in diameter, was excavated through Hudson River shale of average hardness a distance of 523 ft. Similarly, record speed was attained in the sinking of the downtake shaft of Moodna pressure tunnel in hard Hudson River shale. This shaft was circular, with an average excavated diameter of about 16 ft. 8 in.; commencing at a depth of

365 ft. on March 3d, sinking progressed 177 ft. during the following 31-day period.

An aggregate depth of 4 164 ft. of shaft was sunk from January 1st to December 14th. For the same period the total excavation of full grade and pressure tunnel section was 72 731 ft. Concrete for full aqueduct section was laid in 72 503 ft. of cut-and-cover trench and 20 000 ft. of tunnel were lined, making in all 19.6 miles of waterway section concreted to December 14th.

The largest daily contractors' force actually at work in the field on one day exceeded 16 000. This does not include men in the contractors' camps temporarily not at work, nor those employed in factories and who are not reported.

The total force in the Engineering Bureau of the Board of Water Supply, numbering 1 289 on December 14th, consisted of 306 engineers, 395 engineering assistants and inspectors, 159 clerks, and 429 gage-keepers, laborers and miners engaged in sinking the test shafts at the Hudson River crossing, which latter work has been continued by the Board's forces. The depths reached by the west and east shafts are 994 ft. and 1 085 ft. below river level respectively. Two sets of inclined core borings were made commencing from the shafts, whose zones crossed 1 500 ft. and 960 ft. below the above datum. A vertical boring in the middle of the river was continued, and at a depth of 768 ft. was lodged in rock, probably a boulder, when work was discontinued for the winter.

The exploration work at this crossing was fully described in a paper which was read before the Society during the year.

Surface and sub-surface location surveys, specifications, drawings and contract forms were entirely completed for the City tunnel portion of the Catskill Aqueduct extending 18 miles from the City's northern boundary to two terminal shafts in Brooklyn. Besides these, 22 intermediate shafts were designed. Twenty of the shafts will serve after construction as draft connections to the existing distribution mains, two will connect respectively with the new Croton Aqueduct at Jerome Park reservoir and at the West One Hundred and Thirty-fifth Street gate-house, and two will serve as drainage shafts. The shafts will vary in depth from 210 ft. to 720 ft. The tunnel, circular for its entire length, will have a diameter diminishing from 15 to 11 ft.

DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY.

On January 1st, 1910, there were six separate and independent bureaus covering the work of maintaining, operating and extending the water-works system of the City of New York, and in addition, the Aqueduct Commission had charge of the new works in the Croton watershed. Before the close of March, the six bureaus were consolidated under one head, designated as the Chief Engineer of the Engineering Bureau. The construction and maintenance work were separated into two general groups, the organization being as follows:

CHIEF ENGINEER—Construction of new work, Division Heads reporting direct to Chief Engineer.

- Civil Engineering Designing Division,
- Mechanical " " "
- Miscellaneous Construction "
- Water Main Construction "
- Inspection "
- Laboratory "

DEPUTY CHIEF ENGINEER—Maintenance and operation of existing works, Borough Engineers and Division Heads reporting through the Deputy Chief Engineer to the Chief Engineer.

- Borough Engineer—Manhattan and the Bronx.
- " " Brooklyn.
- " " Queens.
- " " Richmond.
- Contracts and Statistics Division.
- Real Estate Division.
- Water Measurement and Water Waste Division.

This reorganization has resulted in a reduction in payrolls and expenditures for supplies, amounting to over $200 000.

In June, pursuant to an act of the Legislature, the work formerly carried on by the Aqueduct Commission was placed under the Department of Water Supply, Gas and Electricity, and the engineering corps of this Commission formed a new division, reporting directly to the Chief Engineer.

MANHATTAN AND THE BRONX.

The Croton Falls Reservoir has been completed and adds 15 753 million gallons to the storage capacity of the watershed, bringing

the total storage capacity, including flashboard equipment, up to 104 442 million gallons. A description of this reservoir appears among the papers presented during the year.

Two new pumping engines have been installed in the Ninety-eighth Street Pumping Station, having a total capacity of 36 million gallons daily, which is over 50% of the capacity of the entire main high service, for which these pumps were installed.

Extensions have been made to the distribution system, amounting to about 45 miles of pipe, making the total mileage 1 283.

The high-pressure fire system has been extended on the east side, about 32 miles of mains having been laid, making a total of about 88 miles. The new area protected is about 820 acres.

Brooklyn.

Two new driven well stations have been completed and put in service, and the yield of existing stations increased so that about 15 million gallons daily additional have been obtained.

The work of completing the new Ridgewood Station has been advanced so that the pumps are now being erected, and before the summer of 1911 this much-needed addition to the pumping capacity will be available; the nominal capacity of the four new engines is 76 million gallons daily, or about 60% of the present pumping capacity at this station.

The 72-in. steel pipe conduit, running from the Suffolk County line to the Ridgewood Pumping Station, was completed and put in use, thus giving about 40% increase in conduit capacity.

The distribution system has been extended by the laying of about 26 miles of mains, the total mileage in use being about 918.

The high pressure fire service system is being extended in the Park Slope, South Brooklyn and Gowanus sections, good progress having been made in the laying of mains. This extension will cover an area of about 1 300 acres.

Queens.

New wells have been driven at the Bayside and Whitestone Stations, and the filter plant at the Bayside Station is nearly completed.

A 30-in. main, about 5 miles in length, has been laid to carry an additional supply from the Citizens Water Supply Company's plant to the First Ward.

Studies have been made for an adequate distribution system for the First and Third Wards.

About 6 miles of mains have been laid to extend the distribution system, the total mileage to date being 169.

Richmond.

A comprehensive development of local sources of supply has been laid out and contracts prepared. It is expected to increase the existing supply by about 5 million gallons daily, equivalent to over 50% of the present supply of slightly less than 9 million gallons daily.

About 17 miles of mains have been laid in extending the distribution system, the total mileage to date being approximately 186.

DEPARTMENT OF DOCKS AND FERRIES.

Piers.

During the year three new piers and one pile platform have been built on the North River, and eight piers have been extended to the bulkhead line as now established. On the East River one pier and five platforms were built in the Borough of Manhattan. Two piers have been built in the Borough of Brooklyn.

Bulkhead Wall.

Seventy lin. ft. of bulkhead wall have been constructed on the North River and 525 ft. on the East River, and in the Borough of Brooklyn 2 105 lin. ft. have been completed.

New Wharfage.

The new bulkhead wall built during the year aggregates 2 700 lin. ft., making a total new wharfage of 14 100 lin. ft. with a new pier area of 634 780 sq. ft.

Ferries.

At the St. George Terminal, a ramp approach to the ferry, in extension and continuation of the inshore portion built by the

Borough of Richmond authorities, extending from Jay Street to the established bulkhead line, has been completed with the exception of paving. A new steel viaduct connecting Jay Street at St. George with the ferry terminal buildings has been built as an approach for trolley cars and foot passengers.

The reconstruction of the East Twenty-third Street and Roosevelt Street Ferries has been completed, and the reconstruction of the Broadway Ferry Terminal in Brooklyn, with which the two former terminals are to connect, is well under way. The City has leased the privilege of operating these ferries to the Brooklyn and Manhattan Ferry Company.

Freight Sheds.

A steel freight shed, 1 453 ft. long and 142 ft. wide, has been built on the Thirty-first Street Pier, at South Brooklyn.

The construction of a single story freight shed on the pier at the foot of West One Hundred and Thirty-first Street, Manhattan, is in progress.

Freight Terminals.

Several studies have been prepared looking to the adoption of a plan for the consolidation of traffic requirements of the various trunk line railroads entering the west side of the Borough of Manhattan, so that freight and merchandise may be received and taken directly from car floats or piers into combined factory and warehouses where the freight may be distributed either upon foreign freight cars for distribution at remote points outside of the City of New York, or on to trucks for local distribution, or into factory portions of the warehouses for manufacturing purposes, and also providing for the reception of freight and merchandise in a reverse manner. This constitutes the terminal warehouse proposition now being considered by the Department, and when carried into operation will result in the releasing of several piers from leasehold bondage by making them available for a more general public use.

The precise locality at present being considered for this purpose comprises the waterfront between West Twenty-fifth and West Thirtieth Streets and the blocks in the rear, extending back to Tenth Avenue. Other additional sites for terminal purposes also being considered are the three blocks between West Houston and

Spring Streets, and the block now occupied by Washington Market, which latter is City property. The scheme admits of expansion by its application to other localities along the waterfront as the requirements and exigencies of the traffic conditions demand. The grand result of this idea will be the elimination of a great mass of the congestion in the matter of temporary storage and handling of freight, which now occurs both in the streets and on the piers themselves, as no freight would be permitted to remain on the piers at all.

The relief afforded traffic conditions under these circumstances is so far-reaching that it is expected that the co-operation of the railroads, which is essential to the successful accomplishment of this plan, will be secured.

Chelsea Improvement.

The nine piers comprising the Chelsea Section improvement have been equipped during the year with heat, light and power for operating hoisting winches and elevators, and have been reduced to an actual revenue producing proposition during the past ten months by the occupancy of the entire section by its accredited lessees, namely, the Cunard Steamship Co., occupying Piers 53, 54 and 56; the French Line, Pier 57; the Atlantic Transport Line, Pier 58; the White Star Line, Piers 59 and 60; and the American Line and Red Star Line, Piers 61 and 62. All of the steamers of these companies entering the Port of New York have for ten months been successfully accommodated at the Chelsea Section.

Jamaica Bay.

As hereinafter referred to in discussing the work of the Jamaica Bay Commission, the planning of this improvement passed into the hands of the Commissioner of Docks and Ferries on May 1, 1910.

A map showing the harbor lines, the first requisite to any physical improvement, together with lines defining the various basins, has been prepared by the Department, and is now being considered by the Harbor Line Board, after which that Board will report to the Secretary of War the results of its consideration in the matter. Any changes that are suggested by the Secretary of War will be promptly made, the map re-submitted, if necessary, and upon its

final approval by the Secretary of War, the outermost lines and channel lines limiting dredging will be fixed. This will be promptly followed by the submission of a map to the Commissioners of the Sinking Fund for their approval, showing the general new plan of improvement which the Department expects to adopt. This map is now ready and provides for establishing a bulkhead line inshore of that for which the War Department's approval has been requested for the greater extent of Jamaica Bay, and the limiting lines will therefore become either the coincident bulkhead and pierhead lines or inshore pierhead lines, which in the aggregate, cover about 319 000 ft. or 60 miles, extending from a point 350 ft. west of West End Avenue, Manhattan Beach, in Sheepshead Bay, and along the northerly shore of Rockaway Inlet, the westerly, northerly, easterly and southerly shores of Jamaica Bay, Boroughs of Brooklyn and Queens. For a stretch of about 55 000 ft., provision is made for piers 1 000 ft. long, and for a stretch of 42 000 ft. piers 300 ft. in length may be built. Fifteen basins, varying in width from 200 ft. to 1 700 ft., and in length from 1 800 ft. to 12 000 ft., are laid out.

The plan also provides for a channel 1 000 ft. wide with a length of about 100 000 ft., widening to about 4 000 ft. at Rockaway Inlet.

The general length of Jamaica Bay, in its unimproved state, in an easterly and westerly direction, is 6½ miles, and the width in a northerly and southerly direction, is about 4½ miles, with a perimeter of about 31 miles.

Inshore of the bulkhead line a marginal street and an area for future development will extend all around the proposed improvement, varying in width from 50 ft. to 1 700 ft.

Within the broader areas, it is proposed to provide accommodations for an interconnecting wharf railroad, with spurs connecting with combined factory and warehouses, and general storage or car yards; for a belt-line railroad encircling the entire improvement with branch connections at intervals with main lines; for a marginal street with direct connection with the general street system of the boroughs; and for transverse streets at intervals for team traffic, connecting the marginal street with the waterfront and with the warehouses, and at the same time affording locations for main trunk sewers.

A number of general studies for this development have been made, but no final plan of development in detail has as yet been adopted, nor can any such plan be adopted until after the Commissioners of the Sinking Fund have approved the general outline.

JAMAICA BAY IMPROVEMENT COMMISSION.

At the close of 1909 this commission submitted its report to the Board of Estimate and Apportionment, recommending the procedure to be followed in developing the northern and western portions of Jamaica Bay. At the beginning of the present year it took up the consideration of the details of harbor lines of the southerly portion, this extending from Rockaway Point eastwardly beyond the Long Island Railroad trestle.

The City Charter places jurisdiction over all waterfront work under the Commissioner of Docks and Ferries. It being evident that before the actual construction of this great waterfront improvement could be undertaken it would be necessary to place the entire control over it under the Dock Commissioner, the special commission was directed to complete its work and submit its final report on or before May 1st. These instructions were carried out by the commission which presented, with its final report, a plan showing the location recommended for the previously undesigned harbor line, and tables giving the geographical position of the triangulation points which had been determined during the course of the work.

The commission turned over all of the data in its possession to the Department of Docks and Ferries and went out of existence on May 1st, 1910.

A review of the entire project was made the subject of a paper presented during the year by one of the Commissioners.

DEPARTMENT OF BRIDGES.

Manhattan Bridge.

The track work on the anchorages and the approaches was completed during the year, and the contract work on the railings, stairways, pavement and electrical equipment, has also been practically finished. The roadway of the bridge was opened for vehicular

traffic on December 31st, 1909, and the easterly footwalk was opened to the public on July 18th, 1910. A contract has been let for the construction of movable platforms for use in inspecting and painting the under portions of the bridge. Plans have progressed for the treatment of the plazas at the terminals.

The erection work on this bridge was described in a paper presented during the year by the Chief Engineer of the Department, and appears elsewhere in the record of the year's proceedings.

Queensboro Bridge.

Movable platforms have been erected for use in inspecting and painting the under portions of the bridge; a contract has been let for the construction of toll houses and police shelters; and a contract will be let within a short time for the erection of stairways in the Manhattan anchor pier and for the erection of elevators in the Queens anchor pier. As the Queens anchor pier is approximately ½ mile from the Queens end of the bridge, access to the bridge at this pier will be a convenience to a large number of people. Plans have been prepared for the equipment of the outer tracks on the lower deck and the laying of conduit tracks on the plaza in Queens. This work will enable the operation of cars over the bridge, franchises for such operation having already been granted by the Board of Estimate and Apportionment.

Madison Avenue Bridge Over the Harlem River.

The Madison Avenue Bridge was completed and opened to the public on July 18th, 1910. The cost of this bridge was $1 202 275.32. It has two roadways, each 37 ft. wide, and two footwalks each 9 ft. wide. On each roadway is a surface railway track adaptable for either the overhead or underground system of electric operation. An inspection of the Bridge was made by the Society in March last.

The temporary bridge in use during the construction of the new one has been removed at a cost of $4 287.

University Heights Bridge Over the Harlem River.

The floor system of the bridge was strengthened and two trolley tracks have been laid. This work will enable the Union Railway Company to operate over the bridge under a franchise which has

been granted by the Board of Estimate and Apportionment. At the time these tracks were laid the asphalt pavement on the bridge was replaced by wood block pavement.

Eastchester Bridge Over Hutchinson River.

A contract was let at a price of $11 691 for the construction of a temporary bridge for use during the building of a new permanent bridge on the line of Boston Road. The work on this temporary bridge is nearly completed.

Pelham Bridge Over Eastchester Bay.

A contract was let at a price of $32 966 for constructing the ornamental towers on this bridge, and for the completion of the railings, gates, electrical equipment and other details.

Hunters Point Avenue Bridge Over Dutch Kills.

The construction of the new bridge has been completed; it consists of a double-leaf bascule bridge with a clear span of 60 ft. The roadway is 36 ft. wide and the two sidewalks are each 6 ft. wide. The contract price was $95 214.11.

Municipal Building.

The foundations for the Municipal Building were completed during the year at a cost of $1 351 422.13. The foundations for the main columns of the building consist of 106 caissons, of which 68, comprising those under the tower and the southerly portion of the building, extend to bed rock at elevations varying from —74.69 to —112.07 ft. The remaining caissons, under the northerly portion of the building, rest on sand at an elevation of about —40 ft. There are 65 rectangular caissons varying in size from 5 ft. 6 in. by 11 ft., to 26 ft. by 31 ft. The 41 circular caissons vary in diameter from 6 ft. 6 in. to 14 ft. 2 in.

The contract for the completion of the substructure, the erection of the superstructure, and the installation of plant, exclusive of interior finish, was let on December 31, 1909, at a price of $5 895 000. The fabrication of the steel, the cutting of the granite facing stone and the preparation of the various materials needed under this contract have progressed during the year. The steel has been delivered

and erected to the height of the street level. In October the foundation work was inspected by members of the Society.

INTERSTATE BRIDGE.

The New York and New Jersey Interstate Bridge Commission have carried on a continuous investigation of various sites for a bridge crossing of the Hudson River, and have had borings made across the river about opposite West One Hundred and Seventy-ninth Street, and about opposite West One Hundred and Tenth Street. The borings at each of these sites have located rock bottom at reasonable depths on each side of the river, but no hard bottom has been discovered within reasonable foundation depths in the center of the river at either site.

It therefore appears that the crossing will have to be made in one span between harbor lines.

The Commission is still continuing its investigations to ascertain the probable cost of the proposed bridge.

DEPARTMENT OF PARKS.

Boroughs of Manhattan and Richmond.

The construction of the southerly portion of Colonial Park, the physical adjustment of John Jay Park to meet the recent change made in its boundaries, and the construction of the chain of parks in Broadway, between West One Hundred and Tenth and West One Hundred and Twenty-second Streets, were begun during the year and the work is now well advanced, while the Chelsea Park improvements have been completed.

Repairs have been made to the Battery sea wall, 25 000 lin. ft. of pipe rail fences have been erected in the City parks, and 300 000 sq. ft. of rock asphalt mastic sidewalk pavement has been laid. A contract has recently been entered into for laying the sidewalk on the Richmond Turnpike boundary of Silver Lake Park in the Borough of Richmond.

The remaining work in these boroughs related to the maintenance of the roadways, all of which have been kept in good repair, and the preliminary work for playground improvements for which an authorization has been given.

A suggestion has recently been made to the Sinking Fund Commissioners by the Commissioner of Docks and Ferries and by the Commissioner of Parks for the reclamation of about 40.6 acres of land under water on the westerly side of Riverside Park, extending from West Eighty-third Street to West One Hundred and Twenty-ninth Street, at an estimated cost of about $1 000 000, and an appropriation of about $233 000 has been urged to permit of immediately improving the section south of West Ninety-fifth Street. The plans submitted for this improvement contemplate the use of ashes and of material from the subway excavations for the filling, and for ultimately giving up the area between the river and the New York Central Railroad tracks to commercial purposes with an esplanade occupying a higher level extending from the retaining wall to the waterfront.

Boroughs of Brooklyn and Queens.

The most important work finished during the year in these boroughs related to the grading and paving of Bay Ridge Parkway (Shore Road extension) from its junction with Fort Hamilton Avenue at Sixty-seventh Street to its southerly terminal at the former street, comprising a length of about 0.8 mile. The roadway has been given a width of 40 ft. and a wearing surface of Hudson River road gravel, four inches thick laid on a 5-in. trap rock foundation. Vitrified brick gutters have been provided, laid on a concrete foundation. The total cost of this improvement was $68 067.59.

The bridge on the line of First Avenue over the Shore Road was begun during the year and is now about 40% complete. The exposed work is of a Hurricane Island granite, with arches of "Gustavino" construction. The construction of this bridge has necessitated the re-arrangement of the lines and grades of Shore Road as well as several changes in the grade of the adjoining streets. The bridge is estimated to cost $89 800.

The westerly traffic roadway of Ocean Parkway was paved with sheet asphalt between Eighteenth Avenue and Kings Highway, as was also Parkside Avenue between Flatbush Avenue and Park Circle.

A granite stairway has been constructed on the Fifth Avenue side of Sunset Park, a new tennis house has been built in Prospect Park, and a shelter has been erected in Fulton Park. The McKib-

ben and White Streets playground was completed during the year at a cost of about $15 000. For a substantial number of the improvements undertaken, department labor was used and was responsible for the construction of the small comfort houses in Lincoln Terrace and Canarsie Park. During the coming year it is proposed to construct the sea wall along the shore road between Bay Ridge Avenue and Ninety-second Street, to excavate the lagoon in Dyker Beach Park, and to construct a number of playgrounds.

Borough of the Bronx.

The roads in Bronx and Pelham Parkway and in Pelham Bay Park have been reconstructed and surfaced with asphaltic mixtures and asphaltic concrete, making them practically dust-proof and capable of resisting automobile traffic. To relieve the congestion on the main driveway an asphalt block pavement has been laid on the southerly side of the Bronx and Pelham Parkway between White Plains Road and the New York, New Haven and Hartford Railroad.

A reinforced concrete arch foot-bridge was built over the Bronx River gorge at a point about 200 ft. south of the Lorillard Falls. This bridge has a single span of 90 ft. and a width of 15 ft. Concrete was used for the parapet and spandrel walls and granite for copings. It is located at one of the most picturesque points on the Bronx River, and replaces an unsafe and unsightly wooden bridge.

The construction of a brick sewer 8 ft. in diameter, required for carrying the drainage from Van Cortlandt Lake to the Broadway sewer, is now well advanced. On its completion the marsh land traversed by the stream through which the lake now drains will be reclaimed and converted into playgrounds.

The Colonial Garden in Van Cortlandt Park has been raised, drained and improved, and canals have been spanned with five concrete arch bridges. The dam near the boathouse in the Zoological Park, built in 1852, has been reinforced with concrete and faced with rustic stone, and the old dike at Macombs Dam Park has been repaired; the latter work, together with new crib, has resulted in greatly improving the appearance of the shore line in its vicinity.

Additional green-houses are now being constructed in the Botanical Garden and near the Lorillard Mansion, and the new administration building in the Zoological Park has been completed.

A granite and limestone fountain was erected at the junction of Jerome Avenue and Viaduct Road at Macombs Dam Park.

DEPARTMENT OF STREET CLEANING.

The jurisdiction of the Department of Street Cleaning is limited to the Boroughs of Manhattan, Brooklyn and the Bronx, the similar work required in the Boroughs of Queens and Richmond being placed under the control of the President of each of the boroughs.

Statistics recently compiled by the department show the following items of interest:

Ashes removed daily	8 300	tons.
Garbage removed daily	1 100	"
Light refuse removed daily	600	"
Total	10 000	tons.

The ashes are used for filling and reclaiming 173 acres of land formerly under water adjoining Rikers Island, while the garbage is reduced at Barren Island, none of the waste being dumped at sea. To carry out this work a fleet of 56 scows is maintained.

The average waste handled per day by each of the department drivers is 6.25 tons. The department has 2 967 sweepers in its employ, these men caring for an area of 23 827 229 sq. yd., or an average of over 8 000 sq. yd. per man per day. The cost per capita per year for the entire service of the department is about $1.73.

Snow removal is usually provided for by contract; this work embraces over 400 miles of streets averaging 60 ft. in width. Garbage reduction is also made the subject of a contract which involves the annual expenditure of $215 000.

A series of experiments were carried out during the past year to determine the most economical and efficient method of flushing street surfaces. The results were published in the *Engineering News* of April 14, 1910, and indicated that flushing machines, operated under pressure, required 400 gal. of water per 1 000 sq. yd. cleaned, while squeegees or machines equipped with a revolving spiral rubber scrubber located back of the nozzles and designed to collect the filth and deposit it on one side, could be operated with 175 gal. of water per 1 000 sq. yd. The amount of water required for this work when using hand hose is about 1 700 gal. per 1 000

sq. yd. In case the flushing process is adopted it is proposed to place screens at the inlets of receiving basins so that only the finest particles of débris will reach the sewer, and to make the work the subject of a contract covering a 5-year period.

REFUSE DISPOSAL.

Plans have been prepared and bids will shortly be received for the construction, in the Borough of Richmond, of another refuse destructor of high temperature and utilization type, based on the successful experience and long experimenting at the New Brighton plant.

CITY PLAN.

Borough of Manhattan.

With the exception of the Inwood Hill section, located north of Dyckman Street, this borough has been fully mapped.

A tentative plan has been adopted during the year, providing for the extension of Seventh Avenue southwardly to West Broadway, thereby opening up an artery of traffic through a portion of the City which has been dormant for many years and which it is believed will ultimately provide a desirable subway route.

A plan has also been considered providing for restoring the lines of Riverside Drive in the section between West One Hundred and Fifty-fifth Street and Dyckman Street, it having become evident that the improvement could not be carried out along the lines adopted in 1908 except at a prohibitive expense. It is expected that the readoption of the old plan will be followed by modifications more consistent with the existing lines than was originally contemplated.

The laying out of a tunnel street, based on the acquisition only of such rights as are needed for construction purposes between planes located approximately at the tunnel roof and at sub-grade, and leading from Broadway near Fairview Avenue to the subway station at West One Hundred and Ninety-third Street, has been adopted, and proceedings are about to be begun for the acquisition of title. This proceeding will be unique, inasmuch as no attempt has heretofore been made to limit street rights either overhead or underneath.

Borough of Brooklyn.

With the exception of the area adjoining Jamaica Bay, a street system has been provided for all of the territory within the limits of this borough.

During the year rule and damage maps have been prepared for 54 opening proceedings, comprising 90 streets having a total length of 54.3 miles. Filing maps for 83 changes in street lines and grades, affecting a total length of about 100 miles, have also been prepared.

The most important map modifications which have been effected during the year comprise the laying out of Kings Highway between Ocean Parkway and Flatbush Avenue, and the provision of a street system for the territory adjoining Paerdegat Basin north of Flatlands Avenue, the latter changes including provision for here discontinuing the basin.

A study has also been made, and a map has been prepared showing an adjustment required in the street system adjoining the Long Island Railroad extending from New York Bay to Flatbush Avenue, a distance of about 5 miles.

Plans and profiles for grading contracts in this borough are prepared by the Topographical Bureau. The work of this character done during the year 1910 has related to 183 improvements, having a total length of 48.3 miles.

Borough of the Bronx.

The Borough of the Bronx has an area of 26 523 acres, of which 12 317.5 acres are located west of the Bronx River.

The final maps for the latter area were completed in 1895 and included provision for about 375 miles of streets, of which about seventy-five (75%) per cent. have now been legally opened.

East of the Bronx River, the Tentative Plan of the Street System is nearly completed and 10 final sections, of which there are thirty-four in this district, have been filed, with dimensions and grades. There will be about 450 miles of streets in this district.

The triangulation in the Borough of the Bronx by the United States Coast and Geodetic Survey in conjunction with the City, was begun October 22, 1904, and finished in the fall of 1905.

The traverses run by the Topographical Bureau connecting the triangulation stations, as a rule, close within one to 50 000. All the

co-ordinates east of the Bronx River were referred to the Northwest Quadrant and all of the maps are or will be based on them.

The monumenting of avenues and streets is progressing favorably and 339 special orders were carried out for referencing and resetting monuments which were disturbed in connection with street improvements.

Rule maps and technical descriptions were prepared for 42 opening proceedings; draft damage maps in 51 cases; final damage maps and final benefit maps in 51 cases (comprising 985 maps); and maps, catalogues for sale of buildings in streets where title was vested, in 27 cases.

Forty-five maps, showing the lines and grades of streets, which were approved by the Board of Estimate and Apportionment, were prepared and placed on file in the vault of the Topographical Bureau.

Borough of Queens.

This borough comprises 75 111 acres, of which area 67 174 is land above water. With the exception of a few hundred acres, the topographical survey has been completed, an area of 51 912 acres has been mapped on a scale of 80 ft. to the inch, and 57 529 acres have been shown on a 200-ft. scale. Including the Long Island City section, tentative maps have been adopted for an area of 28 750 acres, and 45 sections of the final maps, comprising an area of 19 865 acres, have been adopted. Three final maps, relating to an area of 917 acres, are now awaiting the consideration of the Board of Estimate and Apportionment, and 6 additional sections, comprising 2 200 acres, have been completed and are ready for submission.

During the year the maps relating to 20 proceedings for the acquisition of title to streets have been completed, as have also 37 maps required by reason of amendment to proceedings previously begun. At the close of the year the maps required for 37 additional proceedings were in various stages of completion.

Studies have been made, and numerous conferences have been held with the engineers of the Long Island Railroad, relative to the elimination of grade crossings between Long Island City and Jamaica, and the maps required in connection with this improvement are now being prepared.

The year's record of progress includes the completion of the map of Queens Boulevard between the diagonal bridge crossing the Sunnyside Yard at Long Island City and Hillside Avenue in Jamaica, a distance of about seven miles. This street is intended to form the principal traffic artery of the borough and is to have a width of 200 ft. in the section north of Union Turnpike and a width of 150 ft. through the remainder of its length.

Borough of Richmond.

This borough comprises an area of 36 600 acres. The primary triangulation, bench leveling and section traversing have been completed, the monumenting is about half done, and the topographical details and field mapping have been completed for about 25 000 acres.

Final maps have been prepared for about 3 465 acres, of which area the maps for about 1 600 acres have been adopted by the Board of Estimate and Apportionment. It is estimated that all of the work incidental to the completion of the survey was at the close of the year 75% complete. The work has been confined to sections where development is most advanced, this representing the most difficult and expensive portion of it. It is believed that it will be entirely completed in about two years.

During the past year tentative maps have been prepared or are in process of completion covering a total area of about 4 400 acres. The tentative maps show a carefully thought out basic system and are being freely consulted by property owners interested in developing their holdings.

PAVEMENTS.

During the past year new pavement has been laid in the various boroughs as shown in the following table, the length in each case being indicated in miles:

Character.	Manhattan.	Brooklyn.	The Bronx.	Queens.	Richmond.	Total.
Sheet asphalt.....	10.40	41.77	0.91	1.17	....	54.25
Asphalt block.....	5.67	3.86	6.28	1.21	0.42	16.94
Wooden block.....	3.57	.....	.....	0.19	0.70	4.46
Brick, slag and stone....	7.52	8.04	3.56	0.23	2.49	21.84
Macadam.....	2.50*	0.80	.....	12.00*	....	15.30
Total.....	29.66	53.97	10.75	14.80	3.61	112.79

* Resurfacing.

The total mileage of pavement in each of the boroughs as reported at the close of the year is as follows:

Character.	Manhattan.	Brooklyn.	The Bronx.	Queens.	Richmond.	Total.
Sheet asphalt	260.78	397.43	88.70	19.95	0.83	717.69
Asphalt block	52.96	27.89	48.45	9.54	9.76	148.05
Wooden block	14.80	2.21	3.40	5.70	1.14	26.75
Brick, slag and stone	109.76	208.09	41.01	42.86	11.69	413.34
Macadam	4.68	110.24	23.34	345.08	196.70	679.99
Total	442.45	745.22	154.90	423.13	220.12	1 985.82

The maintenance problem was made the subject of a paper presented during the year by the Chief Engineer of Highways for the Borough of Manhattan, which has attracted much attention.

Under Chapter 546 of the Laws of 1910, provision was made for the recognition of preliminary pavement in such a way that when laid at the expense of the property owners, it could be replaced by a permanent pavement and a second assessment levied for the excess in cost as compared with that of the preliminary work. This course made it practicable to provide the suburban sections with pavement suitable for their immediate needs and at the same time relieved the City from the burden of having to assume the entire expense of replacing it with more substantial work. The temporary pavement was defined in the bill as bituminous macadam or such other of similar nature as might from time to time be designated by the Board of Estimate and Apportionment. In order to ascertain the merits of pavements suitable for preliminary use, experimental work has been begun in the Borough of the Bronx and is being arranged for by the Borough of Queens, and will be referred to in the discussion of the work in these boroughs.

Borough of Manhattan.

During the year there have been laid 319 000 sq. yd. of asphalt top and binder in making repairs to the sheet asphalt pavement out of guarantee, this representing approximately 13.8% of the entire paved area out of guarantee; the cost of this work was 11.1 cents per sq. yd. For keeping in repair the asphalt block pavement out of guarantee 24 256 sq. yd. were laid, representing 6.4% of the entire

surface maintained; this work was accomplished at a cost of 13.6 cents per sq. yd.

At the close of the year, and as already noted, a unique street plan was adopted by the Board of Estimate and Apportionment, this contemplating a tunnel street extending from Broadway near Fairview Avenue to the new subway station at West One Hundred and Ninety-third Street, which it is proposed to construct as soon as title to the land has been acquired. The estimated cost of the work is about $85 000.

Owing to the injunction which was obtained in 1905 concerning the proposed treatment of West One Hundred and Fifty-first Street, and which was not vacated until near the close of March last, the work of completing the section of Riverside Drive between West One Hundred and Thirty-fifth Street and West One Hundred and Fifty-eighth Street remained almost at a standstill for two years. At the termination of this legal controversy progress was again resumed, but somewhat slowly, owing to the fact that during the two years in which the work was largely discontinued much damage had been wrought by the elements both to the contractor's plant and to the roadway. The work is now practically complete and in condition to turn over to the Commissioner of Parks.

The length of the recent extension to the Drive and as provided for by Chapter 665 of the Laws of 1897, this including the section from West One Hundred and Twenty-seventh Street to West One Hundred and Fifty-eighth Street, is 8 524 ft., or a little over a mile and a half, of which length 2 044 ft. comprises the viaduct between West One Hundred and Twenty-seventh Street and West One Hundred and Thirty-fifth Street. The cost of the land acquired for this purpose amounted to about $3 100 000, while the construction work involved an expenditure of about $4 700 000. The entire cost of this improvement was paid for by the City, with the exception of about $1 500 000 which was assessed upon a large area in the vicinity.

The length of the cantilever structure over the tracks of the New York Central Railroad, extending from West One Hundred and Fifty-third Street to West One Hundred and Fifty-fifth Street, is 730 ft. To the ordinary visitor this section, hanging as it does over the very edge of the river, is perhaps the most interesting

portion of the Drive and it is the most popular promenade for the people in the neighborhood. The tree-planting has been done by the Commisioner of Parks, who has also arranged to oil the surface of the roadway before traffic is permitted.

It has long been recognized that the route followed between West One Hundred and Fifty-fifth Street and West One Hundred and Fifty-eighth Street requires adjustment in order to improve the dangerous intersection resulting at the latter terminal. It is expected that this adjustment will be made in connection with the plans for the extension farther north.

Borough of Brooklyn.

In the early part of the summer an experimental pavement was laid on Washington Street, between Fulton Street and a line 200 ft. north of Johnson Street, this consisting of an old granite pavement laid in regular courses about three inches apart, the space between blocks being filled in with a white oak wedge. With this combination it is hoped to save the granite blocks, to secure a level surface, to obtain a rigid and water-tight pavement, and to decrease the noise. The work has not been completed long enough to permit of making a satisfactory report concerning the results, but up to the present date they are promising. In case the experiment proves to be entirely successful the way will be clear for utilizing old granite blocks, thereby greatly decreasing the repaving expenses.

Borough of the Bronx.

The most notable improvements carried out in this borough during the year consist of the construction of the Jerome Avenue Bridge across the Mosholu Parkway and of the bridge over the Bronx River at East One Hundred and Eightieth Street. The former, which is now well advanced toward completion, is a reinforced concrete structure and will cost about $80 000. The latter bridge is of concrete and masonry, and will cost about $40 000. The total value of work placed under contract during the year has been about $1 300 000.

For the purpose of ascertaining the merits of various classes of temporary pavement a series of experimental pavements have been laid in White Plains Road, between Boston Road and Burke Street,

a length of about 4 100 ft. The traffic is here expected to be very heavy, and concentration has been effected by limiting the improvement to the section of the street between the railway tracks and the easterly curb. The work was divided into 18 sections, each section being made the subject of a separate experiment. Accurate cost data has been kept and an analysis has been made of the bituminous binders used. The following is a description of the various sections:

Section 1.—A concrete foundation was laid to a finished depth of 4½ in. in proportions of 1:3:6.

The paving mixture consisted of the following mineral aggregates by weight: 73% paving gravel, 19½% sand, 1½% dust, and 6% Bermudez asphalt, 55° penetration. The mixing was done at the Barber Asphalt Plant, then laid at a temperature of 220° and rolled to a finished depth of 1¾ in. with a 10-ton roller.

Over part of this section a seal coat was applied, using ¼ gal. of asphaltic cement to the square yard, over which sand was spread.

Section 2.—The foundation course consists of 1½-in. crushed trap rock, spread and thoroughly rolled with an 18-ton roller to a finished depth of about 3¾ in.

The paving mixture is composed of two parts crushed trap rock passing through a 1¼-in. ring and not containing more than 5% dust, one part sand, and 7% by weight of Bermudez asphalt 55° penetration. The mixing was done at an asphalt plant, and the paving mixture laid at a temperature of 220° and rolled to a finished depth of 2½ in. with a 10-ton roller.

Over part of this section a seal coat was applied, using ¼ gal. of asphaltic cement to the square yard, over which chips were spread and rolled.

Section 3.—A concrete base was laid to a finished depth of 4¾ in. One and one-half inch stone was spread to a depth of 6 in.; then screenings and cement mixed dry in proportions of 3:1 were spread, rolled and sprinkled with water, the operation being repeated until the voids were filled. An 18-ton roller was used.

The paving mixture was composed of two parts crushed trap rock passing through a 1¾-in. ring and not containing more than 5% dust, 1 part sand, and 8% Bermudez asphalt, 55° penetration. The mixing was done at an asphalt plant, and the paving mixture laid at a temperature of 220° and rolled to a finished depth of 2 in. with a 10-ton roller.

A seal coat was applied, using ¼ gal. asphaltic cement to the square yard, over which chips were spread and rolled.

Section 4.—The foundation course consisted of 1½-in. crushed

trap rock, spread and thoroughly rolled with an 18-ton roller to a finished depth of about 3¾ in.

The paving mixture consisted of the following mineral aggregates by weight: 58% ¾-in. stone, 20% ⅜-in. chips, 15% sand, and 7% Standard Oil Company special asphalt binder. The binder, stone and sand were heated on the ground and mixed by hand on mixing boards; the mixture was spread and rolled to a finished depth of 2¾ in. with an 18-ton roller.

Over part of this section a seal coat was applied, using ⅓ gal. to the square yard, over which chips were spread and rolled.

Section 5.—The foundation course consisted of 1½-in. crushed trap rock, spread and thoroughly rolled with an 18-ton roller to a finished depth of about 3¾ in.

The paving mixture consisted of ¾-in. trap rock and 6.7% by weight of Texas macadam binder. The binder was heated and mixed with the cold stone in a standard concrete mixer on the ground. The paving mixture was spread and rolled with an 18-ton roller to a finished depth of 2¾ in.

Over part of this section a seal coat was applied, using about 1¼ gal. Texas 55 Special to the square yard, over which chips were spread and rolled.

Section 6.—The foundation course consisted of 1½-in. crushed trap rock and sufficient screenings to fill the voids, spread and rolled with an 18-ton roller to a finished depth of 3½ in.

The paving mixture was shipped from the Amiesite Plant and laid in two courses. The first course was composed of 1½-in. stone with binder, etc., laid and rolled to a finished depth of 2 in. The second or wearing course was composed of ⅝-in. stone, binder, etc., laid and rolled to a finished depth of 1 in. The paving mixture, therefore, had a finished depth of 3 in. An 18-ton roller was used.

Section 7.—The foundation course consisted of 1½-in. crushed trap rock, laid and rolled with an 18-ton roller to a finished depth of 4½ in.

The paving mixture used is called Asphalto and was mixed at the Sicilian Asphalt Company's plant and hauled to the work and spread. After the paving mixture was comparatively cool it was rolled with a Sicilian Asphalt 10-ton grooved roller to a finished depth of 1½ in. A light layer of cement was then sprinkled over the surface.

Section 8.—The foundation course consisted of 1½-in. crushed trap rock and screenings, spread and rolled with an 18-ton roller to a finished depth of 3¾ in.

The paving mixture consisted of 3 parts ¾-in. stone, 1 part chips, and 6½% by weight of Tarvia X. The stone and Tarvia X were heated on the ground and mixed by hand on mixing boards,

and were spread and rolled with an 18-ton roller to a finished depth of 2¾ in.

A seal coat was applied, using about 0.6 gal. to the square yard of Tarvia X, over which chips were spread and rolled.

Section 9.—The foundation course consisted of 1½-in. crushed trap rock and screenings, spread and rolled to a finished depth of 3¾ in.

The following binders were used in various sections: A mixture of tar and 10% of refined Bermudez asphalt; a mixture of tar and 15% Bermudez asphalt of 60° penetration; a mixture of tar and 15% Bermudez asphalt 110° penetration; Bermudez asphalt of 110° penetration. The paving mixture consisted of 3 parts ¾-in. stone, 1 part chips, and 7% by weight of bitumen. The stone and binder were heated on the ground, mixed by hand on mixing boards and were spread and rolled with an 18-ton roller to a finished depth of 2¾ in.

A seal coat was applied, using about 0.6 gal. of asphalt per square yard, over which chips were spread and rolled.

Section 10.—The foundation course consisted of 1½-in. crushed trap rock and screenings, spread and rolled to a finished depth of 3¾ in.

The paving mixture consisted of 3 parts ¾-in. trap rock, 1 part ⅜-in. trap-rock chips, and 6% by weight of refined tar. The binder and stone were heated on the ground and mixed by hand on mixing boards, and were spread and rolled with an 18-ton roller to a finished depth of 2¾ in. The binder used was refined tar made up in accordance with specifications drawn up by the Office of Public Roads, United States Department of Agriculture.

A seal coat was applied, using about 0.6 gal. to the square yard, over which chips were spread and rolled.

Section 11.—The foundation course consisted of 1½-in. crushed trap rock, spread and rolled to a finished depth of 3 in.

The following paving mixture was used: A sufficient quantity of sand was spread to fill the voids and laid about ½ in. in thickness on top of the foundation course, over which about 1 gal. of Tarvia X to the square yard was applied. One and one-half-in. crushed trap rock was then spread and lightly rolled to a depth of 3 in. About 2 gal. of Tarvia X to the square yard was then applied by the penetration method. A layer of ¾-in. stone was spread and rolled, using an 18-ton roller.

A seal coat was applied, using about 1 gal. to the square yard, over which coarse sand was spread and rolled.

Section 12.—The foundation course consisted of 1½-in. crushed trap rock and sufficient screenings to fill the voids, spread and rolled to a finished depth of 3½ in.

The paving mixture consisted of 1½-in. crushed trap rock, spread and lightly rolled to a depth of 2¾ in. In one portion of this section about 1½ gal. of Sanford & Strains asphalt binder was applied and a layer of ¾-in. stone was spread and rolled. For the remainder the Standard Oil Company's special binder was used.

A seal coat was applied, using ¾ gal. to the square yard, over which coarse sand and chips were spread and rolled. An 18-ton roller was used.

Section 13.—One and one-half-in. crushed trap rock was laid and rolled with an 18-ton roller to a finished depth of 6 in. Sand and cement, mixed in proportions of 1¾ sand to 1 of cement, were forced into the voids of the stone by means of a special pressure machine used by the Hassam Paving Company.

Section 14.—One and one-half-in. crushed trap rock and sufficient screenings to fill the voids were spread, sprinkled and rolled with an 18-ton roller to a finished depth of 6 in. This section is ordinary water-bound macadam, laid as a basis of comparison.

Section 15.—The foundation course consisted of 1½-in. crushed trap rock and screenings, spread and rolled to a finished depth of 3½ in.

The paving mixture was composed of 1½-in. crushed trap rock, spread and lightly rolled to a depth of 2½ in.; 2.3 gal. to the square yard of Tarvia X was then applied, after which a layer of chips was spread and rolled.

A seal coat was then applied, using about ¾ gal. of Tarvia X to the square yard, over which chips were spread and rolled. An 18-ton roller was used.

Section 16.—The foundation course consisted of 1½-in. crushed trap rock and screenings, spread and rolled to a finished depth of 3½ in.

The paving mixture consisted of 1½-in. crushed trap rock, spread and lightly rolled to a depth of 3 in. One and one-half gallons to the square yard of Bermudez road asphalt was then applied, after which a layer of chips was spread and rolled.

A seal coat was then applied, using ½ gal. to the square yard of Bermudez, over which chips were spread and rolled. An 18-ton roller was used.

Section 17.—One and one-half-in. crushed trap rock was spread and rolled to a depth of 6 in.; 1⅓ gal. to the square yard of Standard Oil Company's Binder "B" was then applied, over which a layer of ¾-in. stone was spread and rolled.

A seal coat was then applied, using 1.1 gal. to the square yard of Binder "B," after which chips were spread and rolled. An 18-ton roller was used.

Section 18.—This was an old strip of water-bound macadam

which was swept, after which ¾ gal. to the square yard of Standard Oil Company's Binder "A" was applied, over which sand was spread about 1 in. thick and lightly rolled.

It is proposed to make traffic observations during a prolonged period, and the data thus obtained should be of great benefit in bringing out the advantageous features, both from an economical and traffic viewpoint, concerning each of the methods used.

Borough of Queens.

Arrangements have been made for laying a number of experimental pieces of bituminous macadam on a section of Hillside Avenue, Jamaica, about half a mile in length, the work to be done under the supervision of a committee selected by the Borough President.

It is proposed to use different kinds of binding material and to keep careful records of the cost of the work and of the cost of maintenance for a number of years, as well as a record of the traffic on the street, in a manner somewhat similar to the plan adopted in connection with the experimental pavements laid in the Borough of the Bronx.

This committee was appointed in the fall, but it was believed that the time required for assembling the material and perfecting the necessary organization would carry the actual work into cold weather, so that the results might be inconclusive, and it was decided to defer the experiments until next spring.

Borough of Richmond.

Practically all of the important unfinished contracts relating to the St. George Ferry Approach improvement have been let for more than a year, but the grading and paving of the portion from Weiner Place northerly could not be substantially advanced owing to the delay in finishing the adjoining retaining wall. This work is nearing completion and it is expected that it will be finished and the streets in use before the close of 1911. The total cost of the work will approximate $750 000.

After seven years' service the sheet asphalt pavement laid on Richmond Road at Concord has been replaced by iron slag. The sheet asphalt laid on Richmond Terrace at Port Richmond has been replaced by wooden block pavement after seven and a half years'

use, and wooden block pavement has been laid on Water Street at Stapleton in place of the asphalt block which has had eight years' service.

An experimental pavement composed of oil concrete was laid on Innis Street at Elm Park, and Fingerboard Road has been repaved with asphalt block on macadam foundation.

Considerable work has been done by the Maintenance Division along dust-laying and asphaltic-oil macadam binding lines.

SEWERS.

During the past year sewers and receiving basins have been constructed in the various boroughs as shown in the following table, the sewer length in each case being indicated in miles:

Character.	Manhattan.	Brooklyn.	The Bronx.	Queens.	Richmond.	Total.
Brick and concrete sewer	1.22	5.89	0.51	1.00	2.22	10.84
Pipe sewer	0.30	19.52	7.64	4.75	2.87	35.08
Total	1.52	25.41	8.15	5.75	5.09	45.92
Receiving basins	18	291	94	81	105	589

The total number of receiving basins and mileage of sewers in each of the boroughs, as reported at the close of the year, is as follows:

Character.	Manhattan.	Brooklyn.	The Bronx.	Queens.	Richmond.	Total.
Brick and concrete sewer	405.40	167.54	64.61	24.82	12.01	674.38
Pipe sewer	119.45	688.13	226.80	201.80	75.95	1 312.13
Total	524.85	855.67	291.41	226.62	87.96	1 986.51
Receiving basins	6 366	10 614	3 332	1 695	831	22 858

METROPOLITAN SEWERAGE COMMISSION.

In accordance with the provisions of Chapter 639 of the Laws of 1906 the commission appointed by the Mayor to formulate a plan for protecting the waters of New York Bay and vicinity against

pollution, submitted its final report under date of April 30th, in which recommendations were made of which the following are the more important:

That the metropolitan district should be divided into sections, with boundaries determined in part by the volume of sewage, in part by the facilities offered for disposing of the waste, and in part by the consideration of cost.

That to a considerable extent purification works embodying the principles of screening, sedimentation and filtration should be employed.

That an outline plan should be prepared to which all future sewer improvements should conform in so far as they relate to the ultimate disposal.

That a large portion of the sewage now discharging into the Harlem River and into the upper part of the East River should be outletted elsewhere in order to do away with existing nuisances.

That an adequate degree of purification of sewage from the Passaic Valley and Bronx Valley should be insisted upon.

That the design and construction of sewers should be systematized as far as practicable.

That the carrying out of the policy of conservation proposed should be placed in the hands of a special board of commissioners.

Chapter 200 of the Laws of 1910 provided for extending the term of the commission to May 1, 1913, on which date all of the data collected by them is to be turned over to the Board of Estimate and Apportionment.

Among the investigations of a technical nature carried on during the year are studies on diffusion of sewage through the harbor waters; of the salinity of the waters at the Narrows on incoming and outgoing tides; of currents in the Upper Bay, Jamaica Bay and Rockaway Inlet, and of wind movements throughout the district for 1909; of the float records secured during 1909; of the conditions that would attend the possible pollution of the shipping basins in the proposed Jamaica Bay improvement; of the rate of subsidence of bacteria in the harbor waters, of the putrescibility of these waters, and of the rate at which they will absorb oxygen; and for the determination of nitrates and nitrites. Data have also been compiled relating to the effect of sewage polluted waters on fish.

The works of a practicable nature which have so far been undertaken are more or less of a preliminary nature and include:

An investigation as to the desirability and cost of reconstructing the sewers of Manhattan, on account of interference therewith by subway construction; a study of the feasibility of the collection and disposal of the sewage of Manhattan; a study of the feasibility of screening the sewage of Manhattan and of constructing outlets for more complete dispersion; a study of the sewerage and sewage disposal of Jamaica, Woodhaven and Richmond Hill; seven extensive studies of projects for sewerage of the Jamaica Bay district; two complete studies with estimates of the cost of construction and operation of sewerage works for the Jamaica Bay division of the metropolitan district; studies of improved sewer outlets for Manhattan sewers and of ocean discharge of the sewage of New York, as well as studies to show the impossibility of disposal on Long Island, and other plans which have from time to time been suggested; data regarding the sewers in Manhattan, Brooklyn and the Bronx which lie below high tide level; studies for the diversion of sewage from the Harlem River; selection of sites that would be available for treatment works and for points of discharge into tidal waters without treatment; several studies for the collection and disposal of the sewage from the territory east of Long Island City and Maspeth draining to the East River, particularly for the relief of the districts around Corona, Elmhurst, Woodhaven, Winfield, Flushing, Ingleside and College Point, and for the territory draining to Flushing Creek, together with estimates of cost of several plans. Studies are also under way for the main drainage of Whitestone, Bayside and Douglaston.

The commission has collected and indexed all of the available modern and useful literature on the subject of sewerage and sewage disposal, and is now securing, firsthand, what data can be had from European experience in the clarification and rendering stable the effluents from sewage disposal plants.

Investigation of Points Suitable for Sewer Outlets.

Under an arrangement entered into at the close of 1909, a study was made during the year of the tidal movement of the waters adjoining New York for the purpose of determining upon the points

most suitable for use as outlets. This investigation was made by Colonel William M. Black, U. S. A., who associated with himself Professor Earle B. Phelps. The results of their investigation, in so far as it related to tidal movement, was presented at the November meeting of this Society, and resulted in a most interesting discussion.

In order to demonstrate the feasibility of the projects recommended, the drainage lines of the territory not already provided with a sewer plan were made the subject of study, this embracing nearly all of the Borough of Queens, that portion of Brooklyn adjacent to Jamaica Bay, and a substantial portion of the Borough of Richmond. In connection with the work a series of experiments were made on a process of purification suggested by Colonel Black, based on aeration in connection with or independent of septic action. The results of these experiments have not yet been made available, but it is understood that they warrant a belief that the method can be economically installed at the waterfront without requiring space outside of the street system and without creating a nuisance in their vicinity, and that at the same time the cost of operation, this including sedimentation and screening where required, will compare favorably with any other process now recognized.

The outlets which have been recommended for the undeveloped areas are, with few exceptions, located at points where purification will not be required for some time to come.

It is understood that these studies will hereafter largely guide the sewer bureaus of the various boroughs in the preparation of drainage plans.

Borough of Manhattan.

Most of the work carried out in this borough relates to the reconstruction of old sewers which have either broken down or which have proven to be of inadequate capacity, and the extension of existing outlets to the pierhead line. Sewers have already been constructed in most of the streets, but some of them are of a private character. These are from time to time being replaced by public sewers, and the system is being gradually extended to streets not already provided with drainage. During the year an appropriation of $35 000 was made for the revision of the drainage plan, work on

which, it is understood, will be required to clear the way for carrying out the proposed subway construction.

Borough of Brooklyn.

The construction record for the year, this embracing a total length of about 25 miles of sewers and 16 miles of house connection drains, is one of the largest in the history of the borough. Work on the preparation of assessment lists has been actively carried on and the arrears, which a few years ago aggregated about $5 000 000, has been caught up with.

Drainage plans for an area of 3 206 acres of territory lying north of Coney Island, were adopted this year, thereby completing the plan for all of the territory in this part of the borough excepting a small area covering the easterly portion of Coney Island. A drainage plan for the latter territory has been started and decided upon as far as possible in advance of the adoption of the proper street plan. The sanitary sewage from nearly all of these areas is to be led to a large pumping station located at the intersection of Avenue V and West Tenth Street. The acquisition of the ground upon which to locate the station has delayed any sewer improvements in this neighborhood. Plans for the pumping station, which will be by far the largest one in the borough, are now practically completed.

Drainage plans have also been adopted for an area of 2 191 acres lying to the east of the improved section of Flatbush. The point of discharge of both the sanitary flow and the storm water for this system is tentatively located at Flatlands Avenue and the Paerdegat Basin.

A plan for a new sewer in Flushing Avenue in front of the Navy Yard, designed to replace the present abandoned sewer in this street, with an outlet which will replace the present sewer in Hudson Avenue, was also adopted. This is the largest Navy Yard in the United States. Two large outlet sewers now run through it. One of them discharges behind the Cob Dock and creates a very unsanitary condition at the busiest point along the Yard's waterfront. The construction of the proposed sewer will permit of the removal of both of these outlets.

Drainage plans have also been prepared for practically all of the

territory in the neighborhood of Newtown Creek, not heretofore provided with such plans.

A drainage plan has also been prepared, which will permit of the elimination of the present Johnson Avenue sewer between Knickerbocker Avenue and Gardner Avenue. This sewer has always been a source of trouble and expense and entirely inadequate for the purpose for which it was built. The plan will involve a large outlet terminating at the foot of North Twelfth Street, which will also act as a relief sewer. This outlet will in addition care for the large sanitary flow which will be brought under Newtown Creek at Maspeth Avenue from the Borough of Queens.

A number of smaller drainage plans have been prepared and adopted, the total area involved in such adopted plans for the year 1910 amounting to about 6 400 acres.

The contract for the Motor Pit for the Gowanus Flushing Tunnel has been entirely completed; the contract for the power-house is practically completed; and the machinery for the operation of the flushing tunnel is nearly all delivered and the contractor has commenced to install it. Within a few weeks it is hoped to place the tunnel in operation.

The outlet of the 186-in. interborough sewer in Scott Avenue is now practically completed and may be used for the disposal of storm water. Final payment, however, will not be given until next year, because the street surfaces have not yet been properly restored.

The contracts for the East Ninety-eighth Street sewer, which is the main outlet for a drainage area of 1 000 acres west of Brownsville, have been completed, the third contract is within 30% of completion; and the contract for the outlet for the sanitary sewage, which is 42 in. in diameter and which involves an expenditure of about $100 000, has been let and is well under way. The latter sewer is worthy of note as it is the largest vitrified pipe that has ever been manufactured. Its manufacture was undertaken at the request of the Bureau, because the sewer lies at a depth of from 10 to 12 ft. below ground water, and is to be made water-tight. It is practically the first of the separate sewers which will be built to serve the great area of low-lying land along the south shore, and the experience gained will be of great value hereafter in similar contracts.

The main outlet sewer for the new system in Coney Island was

commenced this year, but has not been completed. This sewer is of 36-in. vitrified pipe and is also being built under difficult conditions. It is laid at a depth of several feet below ground water and is to be water-tight.

Borough of the Bronx.

The storm relief tunnel sewer extending from Webster Avenue to the Harlem River was completed in May last, within the contract time. This sewer is designed to care for the Millbrook watershed north of Wendover Avenue, where it relieves the trunk sewers in Brook Avenue and Webster Avenue. It is proposed to extend this sewer northwardly in order to fully relieve the needs of the section, but a request for an issue of corporate stock to meet the expense was denied by the Board of Estimate and Apportionment on the ground that the cost of the improvement should be assessed upon the property benefited, a principle not recognized in the previous work.

The trunk sewer in Zerega Avenue with a storm-water overflow at the foot of Lafayette Avenue was completed near the close of the year. This sewer drains an area of about 4 000 acres and was built at a cost of $625 433.80.

The trunk sewer in White Plains Road, Lacombe Avenue, Havemeyer Avenue and Lafayette Avenue was placed under contract during the year at an estimated cost of $621 000. This will be the permanent outlet for the large sewers already built.

Borough of Queens.

Contracts have been awarded for the main trunk sewers of the Richmond Hill drainage district, these providing for the discharge of storm water into Jamaica Bay at the foot of Panama Street, and it is expected that the sanitary outlet leading to the Jamaica disposal plant will be authorized early this year. The cost of the work already contracted for in this vicinity amounts to about $518 000.

Drainage plans have been adopted for the Woodhaven section, and outline plans, following the recommendations made by Colonel Black, have been prepared for the drainage of the Corona, Maspeth, Elmhurst, Flushing and Ingleside sections, comprising several thousand acres in the Second and Third Wards. The enormous area

without drainage facilities in this borough and the rapid growth resulting from improved transit will doubtless result in making the branch of the service having to do with these improvements one of the most active fields for engineering work in the immediate future.

Borough of Richmond.

The large outlet and trunk sewers for the Stapleton and Clifton districts have been completed, making a total of ten combined outlet sewers which have been provided in the last nine years, these draining the more populated districts along the north and east shores, located between Holland Hook and Fort Wadsworth.

SUBSTRUCTURE RECORDS.

Borough of Brooklyn.

The investigations made by the bureau in charge of this work have been confined to the older section of the borough and more particularly to the area lying north of the Borough Hall and bounded by Fulton Street, Cumberland Street and the East River. In this section a number of improvements of magnitude have recently been made or are in progress, these including the Gold Street relief sewer, the Manhattan Bridge approach, and the Fourth Avenue subway within the lines of the Flatbush Avenue extension, all of which involve numerous changes in the existing substructures and the introduction of new ones, making it an opportune time for survey and record work. In this section there are located several large power plants, these including the Brooklyn Edison Electric Company, the Brooklyn Union Gas Company, and substations of the Brooklyn Rapid Transit Company. The completion of the investigations in this vicinity will add materially to the value of the records by making it possible to trace the various conduit and pipe lines to the points from which they emanate.

Numerous requests have been made by manufacturing interests for subsurface information, all of which has been furnished, and the value of the records has secured recognition on the part of the various City departments and particularly by the Board of Water

Supply, which is about to construct shafts for the high-pressure tunnels at three points within the area of reference.

Considerable information has also been furnished to the Public Service Commission for use in connection with the plans relating to the Fourth Avenue subway, and the Commission in return has furnished valuable data for incorporation in the records.

Borough of the Bronx.

During the past year the engineering staff of the Borough President was reorganized and subdivided into the Bureau of Design, the Topographical Bureau, the Bureau of Highways, and a Bureau of Sewers, each reporting to the Chief Engineer. In connection with the work of the Bureau of Design, a division of Substructures has been organized.

Heretofore the records of location, size and character of all subsurface structures excepting sewers, have been only partially and poorly kept, and such information as is recorded is widely scattered. Some information relating to water mains is obtainable in the Department of Water Supply, Gas and Electricity, but comparatively little accurate information is available in connection with gas mains, conduits for telephone, telegraph and electric light and power lines, and that only in the offices of the Companies owning them. The desirability of gathering together all this information and recording it in an accurate and permanent manner, is apparent without argument.

This work is now in progress, the information being gathered from the various existing records, and checked, corrected and amplified wherever possible by actual surveys and measurements. All street openings are examined and any exposed structures located; these are accurately plotted in colors on mounted white paper on a scale of 20 feet to the inch, all structures of the same character being indicated in the same color. The horizontal location of any structure can then with reasonable accuracy be determined by scale, and its depth below the surface is noted by figures on the plan.

It is expected that when these record maps are further advanced towards completion, the information shown thereon will be furnished to persons or corporations requiring it, and a reasonable charge made

therefor. This plan is in operation in several other cities, and there is little doubt that the work of this division will be largely, if not entirely, paid for by the fees received for data furnished.

The remaining work of this bureau comprises the investigation and reporting upon proposed work; the preparation of plans, estimates, contracts, and specifications for all construction work; and the examination and report on all matters relating to design and construction over which the Borough President has jurisdiction. It is also charged with the duty of keeping records of the work done, and preparing assessment maps and assessment lists for the Board of Assessors. The latter work was formerly done in part by the Bureau of Highways and in part by the Bureau of Sewers, each bureau carrying out so much of it as naturally fell under its jurisdiction. It is believed that the new arrangement will result in economy, uniformity and standardization.

BUREAU OF BUILDINGS.

The records of the Bureau of Buildings in the various boroughs show that permits for new buildings and alterations of existing ones have been granted during the year as follows:

Borough.	New Buildings.		Alterations.	
	Number.	Estimated cost.	Number.	Estimated cost.
Manhattan.....	888	$96 703 089	3 307	$11 940 066
Brooklyn.....	5 770	84 818 730	4 122	4 983 120
The Bronx.....	2 026	44 034 405	646	1 306 125
Queens.....	4 222	15 345 767	1 257	906 689
Richmond.....	840	3 015 303	433	409 757
Total.....	13 696	$198 912 224	9 825	$19 687 697

A comparison of this record with that of 1909 shows that there has been a substantial decrease in the value of buildings erected in the Boroughs of Manhattan, Brooklyn and Queens, and that the total volume of the year's work represents a value of 24% less than that for the preceding year. The detailed classification of buildings for which erection permits have been granted during the year in the Borough of Manhattan is as follows:

Classification.	Number of Buildings.	Estimated cost.
Dwelling houses estimated to cost over $50 000	7	$1 070 000
Dwelling houses estimated to cost between $20 000 and $50 000	19	750 000
Dwelling houses estimated to cost under $20 000	17	136 800
Tenement houses	208	36 928 000
Hotels	7	955 000
Stores, lofts, etc., estimated to cost over $30 000	149	29 466 000
Stores, lofts, etc., estimated to cost between $15 000 and $30 000	38	799 000
Stores, lofts, etc., estimated to cost under $15 000	43	269 700
Office buildings	44	12 390 600
Manufactories and workshops	33	2 206 900
School houses	11	2 407 000
Churches	11	1 640 000
Public buildings, Municipal	8	3 158 000
Public buildings, places of amusement, etc	40	2 652 100
Stables	60	1 469 720
Other structures	143	409 709
Total	888	$96 708 029

From this table it appears that practically all of the building work of the borough is either for apartments or commercial purposes.

PENNSYLVANIA TUNNEL AND TERMINAL RAILROAD COMPANY.

The work on the Pennsylvania Railroad tunnels and station in New York and the terminal passenger yard in Long Island City, all of which was fully described in last year's review, has been entirely completed. A small part of the north side of the passenger station, together with the two (2) tunnels eastward therefrom under Thirty-third Street and the East River to a connection with the Long Island Railroad near Hunter's Point Avenue, were opened to regular business to and from the Long Island Railroad on September 8th. On November 27th the entire station building was opened to business and the trains of the Pennsylvania Railroad from the west and south began running to and from it. These are the first regular steam-railroad trains to enter New York City from the New Jersey side of the Hudson River. At the time the two tunnels eastward from the station under Thirty-second Street and the East River were put in use, the empty equipment was moved through these tunnels to the newly constructed Sunnyside Yard for storage, cleaning, repairs, etc.

The United States Government is erecting a Post Office building over the station tracks on the block between Eighth and Ninth Avenues, extending from West Thirty-first to West Thirty-third Streets. This building was sufficiently far completed to be put in use at the same time the station was opened.

The power for the multiple-unit cars and electric locomotives, both of which are in use, is received through shoe contacts with a third rail. The main power-house for the generation of the electric power is located in Long Island City, on Front Street near the East River, between Third and Fourth Streets.

All the highway bridges over the Sunnyside Yard were accepted by the City of New York on December 28th, and thrown open to traffic on that day. The magnitude of these bridges is perhaps best shown by the weight of iron used in their construction, as follows:

Hunter's Point Avenue	1,093,804 lb.
Thomson Avenue	3,346,235 "
Bridge Approach	4,682,434 "
Honeywell Street	6,511,641 "
Harold Avenue:	
North	1,212,823 "
South	1,915,834 "
Total	18,762,771 "

About fifteen brick buildings were erected at Sunnyside Yard in connection with its operation.

NEW YORK CENTRAL RAILROAD.

The principal construction work carried out during the past year, affecting that portion of this railroad within the City limits, has been confined to the section between East Forty-second Street and East Fifty-sixth Street, where the remodeling of the terminal arrangements begun in 1903 has been continued, following the lines heretofore reported upon. The old Grand Central Station, which has been a landmark since 1871, was closed in May and was then immediately demolished. It is to be replaced by an entirely new station.

The construction of the Merchants Exchange Building, which will occupy the block fronting on Lexington Avenue from East Forty-sixth Street to East Forty-seventh Street, has been com-

menced. It is designed to be in keeping and to harmonize with the terminal buildings. It will be twelve stories high and is to have a steel frame with granite, limestone, terra cotta, and brick exterior and interior.

NEW YORK, NEW HAVEN AND HARTFORD RAILROAD.

The Harlem River branch of this railroad passes through the Borough of the Bronx, extending from East One Hundred and Thirty-third Street and the Harlem River northwardly beyond the City line to the junction with the main line in the City of New Rochelle. This road carries a very heavy freight traffic, a considerable portion of which originates in the territory traversed by the southerly end of the branch, but the greater portion of it is received by car ferries at the Harlem River from lower New York and at Oak Point Yard, two miles north of the Harlem River, from the railroads having termini on the west bank of the Hudson River. The road originally consisted of two tracks from the Harlem River to a point about one-half mile north of the City limits, and of four tracks from that point to the main line junction. On account of the volume of the freight traffic and the rapidly increasing passenger traffic, it was decided to four-track the road from the Harlem River to the Oak Point yard, and to six-track it through the remainder of its length. An agreement providing for the improvement, and for the elimination of existing grade crossings and for crossings ultimately required, was entered into with the City of New York at the close of 1904. The plans which have been carried out have been made to conform to the street system in use or planned for the borough, and since the work was undertaken the development of the adjoining area has been very rapid. Grade crossings in the Port Morris section at East One Hundred and Thirty-second, East One Hundred and Thirty-third, East One Hundred and Thirty-fourth, East One Hundred and Thirty-fifth, East One Hundred and Thirty-sixth, East One Hundred and Thirty-seventh, East One Hundred and Thirty-eighth, East One Hundred and Thirty-ninth, East One Hundred and Fortieth, and East One Hundred and Forty-first Streets have been replaced by under-crossings, the railroad tracks being carried over the streets by through-plate girder bridges with solid floors, the railroad being constructed on

embankment. The grade crossings at Leggett Avenue, Longwood Avenue, Main Avenue, Baychester Avenue and Bartow, have been replaced by over-crossings, the streets being carried over the railroad on steel bridges of various types, but all having concrete arch floor system of construction supported by regular steel floor beams and steel stringers. The old overhead bridges at Hunts Point Avenue, Westchester Avenue, West Farms Road, Unionport Road, Williamsbridge Road, and Bronx and Pelham Parkway, have been removed and replaced by new steel bridges having additional span and width, and provided with concrete arch floor systems. The old undergrade crossings at Bear Swamp Road, Eastchester Road and Pelham Lane have been replaced by wider structures better adapted to the heavier traffic of the present time.

This branch crosses two navigable waterways—the Bronx River and the Hutchinson River or Pelham Bay. The bridges formerly in use at these crossings have been removed and electrically operated Scherzer rolling-lift bridges have been constructed with provision for a 70-ft. channelway.

The grade crossing at the intersection with the Port Morris Branch of the New York Central and Hudson River Railroad has been abolished through the elevation of the Harlem River branch which crosses the latter road, and a through plate girder bridge with solid floor has been built at this point.

Provision has also been made for additional crossings at East One Hundred and Forty-ninth Street, East One Hundred and Fifty-sixth Street, Lafayette Avenue, Tiffany Street, Barretto Street, Faile Street, Bryant Street, Longfellow Street, Ludlow Avenue, East One Hundred and Seventy-second Street, East One Hundred and Seventy-fourth Street, Tremont Avenue, White Plains Road and Pelham Bay Park, in each case the street being carried over the railroad. All of these bridges have concrete arch type floor construction similar to that provided at other points.

Overhead foot-bridges of steel, with reinforced concrete slab floor construction, have been erected at Van Buren, Melville, Taylor and Garfield Streets. Excepting at Bartow, Pelham Lane, and Park crossings and the wings of the abutments at Bronx and Pelham Parkway and at the Bronx River and Pelham Bay Road bridges, the abutments and piers were built of Portland cement concrete.

The construction excepted from this classification was of second-class masonry with first-class masonry bridge seats on the draw-bridges.

The old wooden stations formerly in use at Port Morris, between East One Hundred and Thirty-fifth Street and East One Hundred and Thirty-sixth Street, at Hunts Point Avenue, and at Bartow have all been replaced by new stations of suitable type, and additional stations have been constructed at Morris Park and at Westchester Avenue. The new stations are provided with granolithic platforms, cover-sheds and subways where required. Granolithic platforms, cover-sheds and subways have also been constructed at the West Farms, Van Nest, Westchester and Baychester stations.

The tracks are laid with 100-lb. rails upon creosoted ties and stone ballast. Automatic block signals govern the train movements.

The general construction work was started early in 1905 and is now practically complete.

HUDSON AND MANHATTAN RAILROAD.

The extension of this railroad in Sixth Avenue from West Twenty-seventh Street to West Thirty-third Street was completed and placed in operation on November 10th. Provision has been made for two tracks, and the type of construction used is similar to that followed in the section south of West Twenty-seventh Street which has now been in operation for more than a year.

The West Twenty-eighth Street station is of the same general character as those which have been provided at West Fourteenth Street, West Eighteenth Street, and West Twenty-third Street. The station at West Thirty-third Street contains three tracks with two platforms, and a concourse where the ticket booths, etc., are located. Five entrances have been provided, these being located at Broadway and West Thirty-second Street, at Broadway and West Thirty-third Street under the elevated stairs, at Broadway and West Thirty-third Street in front of Saks' store, at Broadway and West Thirty-third Street at the corner of the Gimbel store, and in the Gimbel store near West Thirty-second Street. Facilities are provided at this station for handling and checking baggage, these including an escalator for delivering baggage to the street and a chute for sending baggage from the street to the baggage room. The station is

also equipped with a complete blower and exhaust apparatus for ventilation.

The work in this section is complete with the exception of the restoration of the street pavement.

NEW YORK, WESTCHESTER AND BOSTON RAILWAY.

The New York, Westchester and Boston Railway Company was organized to build a railroad from the Harlem River to Port Chester, with branch lines from Mount Vernon to White Plains and from West Farms to Throgs Neck, under a franchise granted by the City in 1904.

The length of the main line and branches above described will be as follows:

Harlem River to Port Chester.....	23.35	miles.
Mount Vernon to White Plains.....	9.39	"
Throgs Neck branch.....	6.41	"
Total.....	39.15	"

The work now under construction comprises the section of the main line extending from West One Hundred and Seventy-fourth Street to the junction with the New York, New Haven and Hartford Railroad in New Rochelle, and also the branch extending from Mount Vernon to White Plains.

Four tracks are to be provided between East One Hundred and Seventy-fourth Street and the junction with the White Plains branch, distant about 1 500 ft. north of the crossing of the New York, New Haven and Hartford Railroad in Mount Vernon, and two tracks through the remainder of the length of the main line and the White Plains branch.

It is estimated that of the 1 700 000 cu. yd. of excavation required about 60% has been completed, and that about 45% of the concrete has been laid, of which a total of about 187 000 cu. yd. will be required.

In the years 1905 and 1906 material for 17 bridges was delivered, of which 13 have been erected. In addition to these bridges, 57 steel structures will be required, these including 30 short-span railroad bridges, 24 highway bridges, 1 four-track subway, 1 two-track viaduct and 1 four-track viaduct, representing about 20 000

tons of steel. Structural material for this work is now being delivered and erected.

Nearly all of the railroad bridges have solid floors, steel trough construction filled with concrete being used on the through bridges, while on the deck bridges a reinforced slab construction is used.

The highway bridges are of deck construction with reinforced concrete floor slabs, and are provided with ornamental hand railings.

The subway, which is 4 000 ft. long, is of the usual construction with cross bents of steel spaced 5 ft. center to center, with concrete arches between bents for both roof and sidewalls.

The two-track viaduct is a slab floor deck structure 700 ft. long, carried on deck cross bents with battered posts.

The four-track viaduct is an open-floor deck structure 900 ft. long, terminating at the north end in a through span 116 ft. long. The deck portion is supported by straight-post cross bents, with posts under centers of tracks, while the through span is supported by concrete piers. The center girders of this through span weigh about 95 tons each and are believed to be the heaviest single girders fabricated. In addition to the steel bridges there are three concrete arches carrying tracks, the spans of which are respectively 20 ft., 50 ft. and 70 ft.

Twenty-seven stations are to be erected on the sections of the line under construction, all of which will be of concrete finish.

Electrical power for the operation of trains and auxiliary equipment will be supplied from the central power station of the New York, New Haven and Hartford Railroad. It will be single-phase at a normal frequency of 25 cycles and a pressure of 11 000 volts. There will also be a supply of three 3-phase power for the operation of auxiliary apparatus such as elevator and shop motors.

For transmission, a substantial catenary overhead construction has been adopted. It will be carried on steel bridges spaced 300 ft. apart on tangent track resting on concrete foundations which are now being built. The catenary construction will consist of a single steel cable of high strength over each track, grounded, and supported on the above bridges. From these supporting cables there will be hung two cross frames 150 ft. apart and 75 ft. from each bridge. These cross frames will carry high voltage suspension insulators, which in turn will carry the "live" track catenaries,

consisting of messenger strand copper conductor and steel contact wire.

There will also be feeders for the signal system, auxiliary feeders for emergency operation, and 3-phase power for apparatus, all carried on the supporting bridges.

Anchor bridges, with electrical control apparatus, will be installed at important junction points, and crossovers, which will provide for automatic sectionalizing of the power system in the event of trouble at any point.

The passenger equipment will consist of steel cars 72 ft. long, seating 86 passengers, and will be operated on the multiple unit system.

The operation of traffic will be regulated and protected by the automatic signal system.

LONG ISLAND RAILROAD.

During the past year the Glendale cut-off, which was constructed for the purpose of connecting the Rockaway Beach branch with the Main Line, thereby securing a connection with the Pennsylnania tunnels, was completed and placed in service, as was also the Montauk freight cut-off connecting the north shore freight yards with the Montauk division. The most interesting feature of the latter improvement is the double track Scherzer rolling-lift bridge which spans the Dutch Kills Creek near the point where it connects with the Montauk division. A connection has been provided at Woodside between the tracks of the Long Island Railroad and the east end of the Sunnyside Yard, this involving the elevation of the railroad as required to carry it over Woodside Avenue and First Street.

The work of reconstructing the Main Line between Jamaica and Winfield was also completed during the year, and third-rail electric trains are now being operated over it between Jamaica and the Pennyslvania station. In connection with this work a new substation was erected at Winfield.

New stations have been erected at Manhattan Beach, Kew, and Jamaica Avenue or Brooklyn Hills; a new station is also in course of erection at Forest Hills. The foundation work has been completed for the proposed eight-story passenger station and office building at Jamaica, and the work of rearranging the yard prior to elevating

the tracks and carrying out other contemplated improvements at this point is now in progress.

Bay Ridge and Manhattan Beach Branches.

Under the direction of the Brooklyn Grade Crossing Commission about 8.6 miles of permanent main and yard track has been laid within the limits of the Borough of Brooklyn. Railroad bridges have been completed and put in service at Avenue L and Avenue P; highway bridges have been provided at Blake Avenue, Sutter Avenue and Seventh Avenue; and a foot-bridge has been built at East Eighteenth Street. Bridges are now under construction at Liberty Avenue and Glenmore Avenue.

The largest bridge built during the year is the one at Seventh Avenue, which has a length of 272 ft.; this bridge has a total width of 70 ft., provision being made for a 44-ft. roadway, two 10-ft. sidewalks and two 3-ft. pipe galleries. It is built on a skew and on a 3% grade. The expenditures during the year have aggregated about $300 000.

BROOKLYN AND BRIGHTON BEACH RAILROAD.

The removal of grade crossings along the line of this railroad, provided for under Chapter 507 of the Laws of 1903 and carried out under the Brooklyn Grade Crossing Commission, is practically complete.

During the past year the bridges at Avenue L and Avenue P, adjoining those on the Manhattan Beach Branch of the Long Island Railroad, were finished and the streets have been regulated and graded at these crossings. The total expense involved in carrying out the improvements last described was $71 165.

CONCLUSION.

In conclusion, I wish to express my obligations to the various heads of departments and corporations who have cheerfully and promptly furnished the data from which the foregoing statements relative to the engineering work of 1910 have been largely drawn. The list is a long one and includes practically all of the engineers or executive officers at the head of the various undertakings described, a large proportion of whom are members of this Society. It is the hope of the compiler that the value of the record as a whole will repay them for their contribution.

ANNUAL DINNER.

The Eighth Annual Dinner of the Society was held at the Hotel Savoy, Fifty-ninth Street and Fifth Avenue, on Saturday, January 7th, 1911. It was a great success, especially in regard to numbers, as it resulted in bringing out 439 members and guests, the largest number that ever participated in any of our banquets.

The President, Mr. Arthur S. Tuttle, acted as Toastmaster, and introduced the speakers of the evening, who responded to the following toasts:

"The City of New York," by Hon. John Purroy Mitchell, President of the Board of Aldermen; "A Mechanical Equivalent of Consciousness," by Hon. George McAneny, President of the Borough of Manhattan; "Congestion and Digestion," by Hon. Cyrus P. Miller, President of the Borough of the Bronx; "Engineering," by Mr. Charles Warren Hunt, Secretary of the American Society of Civil Engineers; "Growth of Modern Cities," by Hon. W. Bourke Cockran; and "The Future City," by Hon. John J. Murphy, Tenement House Commissioner.

During the evening many popular and original songs were sung, and "The Templars" Male Quartet and Mr. Charles Delmont, Bass Soloist, favored the occasion with numerous selections.

A beautiful souvenir title page for the menu was designed by Mr. Delmont, and presented to the Society, which added greatly to the success of the occasion.

The dinner was also a financial success, and netted the Society a small profit over and above all expenditures.

MADISON AVENUE BRIDGE.

INSPECTED BY THE SOCIETY, MARCH 26TH, 1910.

The first inspection of the Society in 1910 was made on Saturday, March 26th, to the new Madison Avenue Bridge, over the Harlem River, about thirty members attending.

This bridge differs from all the others over the Harlem River in that the approaches, instead of having side retaining walls and earth fill, are built of reinforced concrete columns, girders and floor slabs from the beginning of the approaches to the fixed spans, leaving an open space between the old ground surface and the under side of the concrete floor system. Part of this space is to be used for the storage of material and part as a shop for the maintenance and repair of bridges over the Harlem River.

Except under the northerly end of the Bronx Approach where the bed rock approaches the surface, the foundation of the approaches are double rows of piles, driven to hard bottom, under the outside walls and under cross walls about 21 ft. apart. The abutment walls, being wider, have four rows of piles at the street spans and five rows at the fixed spans. Where there are only two piles in a row, the concrete was reinforced by a §-in. square rod each side of the pile. The concrete steel columns, girders and floor slabs are of the usual construction, but especially interesting was the method of erecting and locking the forms, permitting of their easy removal and being used many times over.

The center and rest piers are of concrete, faced with granite, and rest directly on piles without timber grillage. Small houses for the use of the bridge tenders are built on each end of the rest piers with basements to be used as electrical transformer rooms.

The swing span is of the three-truss type having two roadways, each 27 ft. wide between curbs, and two sidewalks each 9 ft. wide and bracketed out from the trusses.

This span is drum bearing with all distributing girders of practically the same depth and in the same plane, making a commodious and convenient engine room.

Two electric motors will be used for turning the bridge, so

arranged that either or both may be used at one time and in either case there will be the same pressure on each of the turning pinions, thereby producing no side pressure on the center pin. One motor will be used for operating the end lifts, which are so arranged that the motor may be run continuously in one direction in raising and lowering. The end lifts are toggles, insuring the ends always being lifted to exactly the same height, driven through connecting rods by cranks on the ends of transverse shafts.

The centering latch is intended to be non-wreckable. It consists of a vertically moving bolt not quite counterbalanced, automatically dropping into a slot or jaw as the bridge swings into place. This jaw is supported on vertical links, and held in place by coil springs, so that, as the bolt drops in, the swinging of the bridge compresses one of the springs, moving the jaw sideways and down, which stops the motion of the bridge, and then the springs return the bridge to its central position. Should the bridge be going too fast the motion of the jaw will be so far down that the bolt will be forced out of the jaw before the limit of the spring is reached, and the parts will resume their normal position without anything being wrecked.

Provision is made for street car tracks and for both the overhead and underground trolley systems. The rails are continued on top of the apron plates with easily adjusted stub joints, thereby doing away with all moving parts.

The thanks of the Society are due to Mr. B. C. Collier, M. M. E. N Y., Engineer for the Contractor, Mr. John C. Rodgers, and to Mr. G. F. Webber, sub-contractor for the concrete steel work, who took great pains to show the members over the work and explain all the details.

UNITED STATES NAVY YARD—BROOKLYN.

INSPECTED BY THE SOCIETY APRIL 30TH, 1910.

The second inspection was made to the U. S. Navy Yard, Brooklyn, on Saturday, April 30th, about two hundred members and friends attending.

The principal object of interest was the battleship *Florida* on the ways nearly ready for launching, with all her inside armor,

boilers, rudder and four propellers and shafts in place, and practically 60% completed. This is a much higher percentage than usual at the time of launching, but was necessitated by there being no nearby dry dock sufficiently large to take this ship.

The *Florida* is 521 ft. 6 in. long, 88 ft. 2⅝ in. beam outside of armor, 47 ft. at midship section from the superstructure deck to the bottom of the keel, and, when finished, will have a draft of 28 ft. 6 in., and a displacement of 21 825 tons. The hull, strictly speaking, has no center keel; the plates are continued across nearly flat, giving a much better bearing on the blocks and greatly facilitating the docking. The bilge keels, which are secured at the turn of the hull or bilge, retard the rolling of the ship and make her steadier in a sea. The main armor belt varies from 11 in. to 9 in. thick; the second belt from 10 in. to 8 in., and the third belt is uniformly 6½ in. thick. The armor will extend from about 6 ft. below the water line to 9 ft. above when the ship is fully loaded.

The turrets, of the balanced type, are five in number, are made of 12-in. sloping armor on the front, 8 in. on the rear, and 3 in. on top, and each will carry two 12-in. guns. There will also be sixteen 5-in. rapid-fire guns, four 3 pounders, two 1 pounders, and in addition two submarine torpedo tubes.

The engines, which were seen in the shops in the various stages of manufacture, are of the Parsons turbine variety, and are being entirely built at this yard. The largest casting weighs about 25 tons, and in material and workmanship cannot be excelled anywhere. There are four sets of engines for going ahead and two on the outer shafts only for backing. Each of the main engine sets consist of a high- and low-pressure engine, with blades varying from ⅝ in. effective length at the entrance to the high pressure, to about 13½ in. long in the final exhaust from the low-pressure cruising-ahead turbine. The initial steam pressure will be 200 lb. and the exhaust to the condenser about 20 lb. The four engines will develop a total of 28 000 h.p. and by means of the four true screws, each 110 in. diameter, 102 in. pitch, will drive the ship at a speed of 20¾ knots.

The first plate of the *Florida* was laid March 9th, 1909; she was launched May 12th, 1910, and is expected to be finished and put in commission in about one year.

The second point of interest was the dry dock No. 4, which when

finished will be large enough to take any naval ship afloat or now building. It will be 700 ft. long and 110 ft. wide at the bottom, 725 ft. long and 140 ft. wide at the top, and will take a vessel 690 ft. long.

This dock was originally intended to be of concrete and a contract was let in 1903 to George Spearin, who drove metal-sheet piling and started to excavate. The quicksands which underlie the whole site caused the sheet piling to collapse, and this contract was declared abandoned in 1907. A contract was then made with the Williams Engineering Company, who drove timber-sheet piling and began excavating, only to meet with a similar collapse of the sheet piling, and they abandoned the contract.

A third contract was let to the firm of Holbrook, Cabot & Rollins November 1st, 1909, who are now sinking to bed rock a continuous wall of pneumatic caissons 5 ft. wide around the dock site, and a series of rectangular caissons 7 ft. square in the body of the dock. After all the caissons are in place, it is intended to excavate the interior, lay a concrete-steel floor and build up the interior wall surface, stepping it off in altars.

The dock at the time of the inspection was only about 30% completed after seven years of actual work.

WORKS OF GENERAL ELECTRIC COMPANY AT SCHENECTADY, AND FILTRATION PLANT AT ALBANY.

INSPECTED BY THE SOCIETY MAY 27TH, 1910.

The third inspection of the year was made to the works of the General Electric Company at Schenectady and to the filtration plant at Albany.

Seventy-five members and their friends left New York on the evening of Friday, May 27th, on the Troy boat, arriving at the General Electric Company works about 9.00 A. M. on the 28th, where they were met by a corps of guides who conducted the members in small parties through the works.

To give a detailed description of all that was seen would require a volume by itself, as it included nearly everything necessary for

the production and use of electricity, from the pouring of a 35-ton casting to the production of the smallest lamp detail.

The works themselves cover an area of 192 acres, and the main street is nearly one mile long. There are 120 buildings, having a total floor area of 3 800 000 sq. ft.; the largest single building, the machine shop, is 295 ft. wide, 800 ft. long, and with the galleries has a floor area of 490 000 sq. ft. There are installed in the works approximately 7 900 machine tools, 200 traveling cranes, 4 500 motors, and 3 700 arc lamps are used to light the building and grounds.

Curtis steam turbine generators are made up to 10 000 kw. capacity from the casting of the parts, the machining, assembling, erecting and testing before shipment. The electric locomotives from the small mine to the heaviest railroad type; the generators and motors, both "A. C." and "D. C.," horizontal and vertical, were seen in all stages, from the separate pieces to the finished product.

The wire itself is not made here, but wire of all sizes is insulated with rubber, braided in the "maypole" machines, spun into strands, taped, made into cables which may be further insulated with fibre, coated with lead, and finally armored with steel wire. Any one or more of these insulations may be used and in almost any order. Commercial rubber for the insulation is first made absolutely pure, then mixed with the ingredients found best for insulation purposes, after which it is ready for use.

In the percelain department all sizes and parts of fixtures, and insulators from the smallest pieces to some standing 3 ft. high, are made. The clay for the larger pieces is weighed for each size, the smaller pieces are gaged by the eye. The molding is made in presses which turn out some intricate shaped pieces; these are first air dried, then sprayed with a solution to produce the glaze, and then baked in the kiln.

The automatic machines turning out finished parts from rough blanks or strips were deeply interesting. In one machine a plain strip of brass was fed in at one end and came out at the other in short pieces, properly shaped, bent, drilled, tapped and a screw inserted near one end.

Perhaps the most noticeable feature in the whole works was the entire absence of calling and shouting, no orders were yelled, every

man knew his duty; in the pouring of the casting, in the transporting by cranes, in the foundry and machine shops, no orders were given in words, all was done by signal without noise. Another prominent feature was the loyalty shown not only by the manager to his men, but also by the men up through their foremen to the manager; a perfect mechanism, every one knowing that in striving to do his duty he will have the full support of all the others.

The last building visited was the works' restaurant, where on the first floor the men could procure a hot meal for 20 cents, the foremen on the second floor could procure practically the same meal, but with a little more "fixings" for a quarter, and here, through the generosity of the General Electric Company, the members and their friends were given an elaborate lunch in a room prettily decorated in their honor and with a service that could not be excelled anywhere.

At the conclusion of the lunch Mr. George E. Emmons, Manager of the Schenectady works, gave an interesting sketch of the history and magnitude of the works of the General Electric Company, and a description of its management. The party left well pleased with the visit, but with sincere regret that it had been so short.

Albany Filter Plant.

The filter plant for the purification of the water used in the City of Albany is located just above the City on the banks of the Hudson River from which the water is taken.

The water is taken from the main channel through a 54-in. pipe under the side channel, and lifted 18 ft. to the sedimentation basin by means of centrifugal pumps. There are three pumps, one of 18 million gallons capacity, and each of the others 15 million gallons capacity.

The sedimentation basin is 323 ft. by 600 ft., with a bottom of 16 in. of puddle, covered with 6 in. of concrete, and sides of the same amount of puddle but covered with 2 ft. of gravel and 10 in. of stone paving. The water is admitted through a series of eleven inlets on one side and drawn off by a series of eleven outlets on the other, with by-pass so arranged that water can be taken direct from the river to the filters.

The water from the basin passes by gravity into the first filters, consisting of a series of covered chambers 19 ft. by 58 ft. by 16 ft. deep, and passing through 2 ft. of sand and 12 in. of gravel, has most of the impurities removed. When the head in one of these filters reaches 5 ft. it is cut out and cleaned.

The second and final filter consists of a series of eight covered chambers, each 121 ft. 4 in. wide, 258 ft. long, and 12 ft. 6 in. high to the top of the arches. The filter bed is made up of 16 in. of gravel and 4 ft. of sand, and the water is carried about 4 feet deep above the top of the sand. The top inch of sand is cleaned every three months, and now the whole bed is being cleaned after eleven years of service. The cleaning is done within the chambers by shoveling the sand into Nichols sand separators, having a capacity of 15 cu. yd. per hour, where the sand is washed and returned to the bed, while the wash water and dirt is discharged outside the filters.

OPEN CUT OF ERIE RAILROAD THROUGH BERGEN HILL.

INSPECTED BY THE SOCIETY JUNE 4TH, 1910.

The fourth inspection of the year was made on Saturday, June 4th, to the open cut of the Erie Railroad through the Bergen Hill, about twenty members attending, and conducted by Mr. A. L. Moorshead, Resident Engineer.

This cut provides for four tracks, and was necessitated by the congestion of traffic in the two-track tunnel. An open cut was adopted in preference to widening the old tunnel on account of the many physical difficulties in the way of widening this old tunnel and maintaining traffic at the same time, and on account of the advantages of an open cut in the handling of traffic and its greater desirability for the traveling public.

The cut is 67 ft. south of and parallel with the tunnel; it is 60 ft. wide at the bottom, about 100 ft. wide at the top, and in all is about 5 100 ft. long. There are four tunnel sections in its length, carrying important streets, and these sections are 190 ft., 285 ft., 235 ft., and 580 ft. long, respectively. Three of these cuts

were tunneled through the solid rock; the fourth one, 580 ft. long, was made by the cut-and-cover method, as there was not sufficient rock roof to permit of tunneling. The cover of this part is a concrete steel arch; the other three tunnels are concrete lined and faced. The earth slopes above the rock have been carefully graded and sodded.

The rock from the cut and tunnels was taken directly to the crusher, which was intended to handle it as fast as excavated, thereby saving rehandling. All of the concrete used about the work was made from this rock, the finer particles being used for sand. The remainder of the rock will be crushed and used as ballast in the road bed at various places on the Erie Railroad.

There will be four tracks in the cut, laid on a rising grade of 0.73% from the level of the present tracks at the westerly end in order to join those tracks and cross under the Lackawanna tracks to the easterly end, where they will be about 40 ft. higher than the present tracks in order to cross over the tracks of the New Jersey Junction Railroad, which in turn cross above the present tracks.

From the easterly end of the cut the tracks are carried on a steel trestle, on a falling grade, to their junction with the present tracks west of the Jersey City station.

The tracks in the cut will be used exclusively for passenger service, those in the old tunnel for freight, and as the freight yard lies both north and south of the passenger station, the advantage of a non-grade crossing of freight and passenger tracks is apparent.

COLLEGE OF THE CITY OF NEW YORK.

INSPECTED BY THE SOCIETY SEPTEMBER 24TH, 1910.

The fifth inspection of the year was made to the College of The City of New York on Saturday, September 24th; about twenty members attending and thoroughly enjoying a trip through a finely and fully equipped college.

This institution was established by the Board of Education in 1848, and called the Free Academy, given its present title by

an act of the Legislature in 1866 and in May, 1900, by another act was placed under the care and control of a Board of Trustees of ten members, nine of whom are appointed by the Mayor, the other being President of the Board of Education.

The five buildings forming the College are of the English Gothic architecture, and were begun in the fall of 1903, and occupied by the College in the fall of 1907. The buildings occupy four city blocks between One Hundred and Thirty-eighth and One Hundred and Fortieth Streets, Amsterdam Avenue and St. Nicholas Terrace.

The main building contains the executive offices, consisting of the Faculty room, the President's room, with private office and rooms for the heads of the various departments, all of which are well furnished, and each department provided with a library and museum containing books and apparatus pertaining to the subjects of that department and an attached laboratory for experimental work and research. The great hall has a seating capacity of 2 200, and is equipped with one of the finest organs in the City. An organ recital is held every Saturday afternoon at four o'clock, and the visiting members had the pleasure of hearing one. The library is large, well stocked with reference and text books, and has a charging system such that any student can see at a glance what, if any, books are charged against him. In the lower part of the building is also a locker-room and concourse for the use of the students during intermission, or when they are not at recitations or laboratory work.

Besides the small recitation-rooms, each department in the building has a large lecture-room and an attached laboratory. Each lecture-room is furnished with a stereopticon, electrically operated shades that, when closed, put the room in total darkness, similarly operated screens and blackboards, and a demonstration table that for completeness in equipment cannot be excelled. For instance, in the physical lecture-room the table is equipped with high and low pressure air, hot and cold water, distilled water, vacuum, steam, gas, and electricity in all its varying intensities of both direct and alternating current. The laboratories are closely connected with the lecture-room by large doors, through a small experiment room.

The individual desks in the laboratories are equipped as com-

pletely as the table in the lecture-room. In this building are taught, not only by books but by experiment where possible, art, including freehand drawing from casts and models, and mechanical drawing; natural history in all its various branches; physics, including mechanics, strength of materials, prime movers, electro-dynamics, astronomy, and surveying; mathematics; history; philosophy; languages, including Latin, Greek, English, French, German, Spanish, and an elective in Italian; education, political science, and public speaking.

Connected with the main building by underground passages are the chemistry building and the mechanic arts building, devoted exclusively to the courses their names indicate. The chemistry building is furnished similar to the main building with lecture-rooms and laboratories, well equipped for making all manner of tests. A shower is located in each of the laboratories, so that should any person catch fire during an experiment the fire could be quickly extinguished. The mechanic arts building contains a pattern shop, foundry, blacksmith shop, machine shop, boiler and engine rooms. The boilers are all alike of the Babcock and Wilcox type, and are used for operating all the buildings, as well as being rigged and run for duty tests. In the engine-room there are four kinds of engines, simple, four-valve, tandem, compound, and cross-compound.

The Townsend-Harris Hall is at present used for the preparatory or academic department.

The last building is the gymnasium, equipped with all the modern appliances for the physical well-being of the students, including swimming pool, showers, rowing machines, running track, basket-ball courts, as well as the well-known fittings.

The college has an enrollment of about thirty-five hundred, of whom 1 459 are in the College proper, 243 in the night classes, and the remainder in the academic department. The degrees conferred are Bachelor of Arts and Bachelor of Science.

To Mr. H. A. Hottenroth, of Geo. B. Post & Sons, architects of the buildings, is largely due the success of the visit, as he had been in charge of the design and equipment of the buildings, and of which he gave the members full descriptions.

SITE OF MUNICIPAL BUILDING AND CENTRE STREET SUBWAY.

INSPECTED BY THE SOCIETY OCTOBER 29TH, 1910.

The sixth inspection trip was made to the site of the Municipal Building and the Centre Street Subway, on Saturday, October 29th.

At the time of the inspection, the foundations of the Municipal Building were completed and the erection of the steelwork had begun.

The foundations for the main columns consist of 106 pneumatic caissons, of which 68, comprising those under the tower and the southerly end of the building, extend to bed rock at an elevation of from — 87.11 to — 112.07 ft.

The remainder of the caissons under the northerly end of the building rest on sand at an elevation of about — 40 ft., and are of such size that the pressure on the sand is six tons per square foot.

There are 65 rectangular caissons, varying in size from 5 ft. 6 in. by 11 ft., to 26 ft. by 31 ft., the largest of which carries six columns. The 41 circular caissons vary in size from 6 ft. 6 in. in diameter to 14 ft. 2 in. in diameter. Rectangular caissons having a width of from 5 ft. 6 in. to 7 ft. 6 in., have wooden working chambers; circular caissons from 6 ft. 6 in. to 8 ft. 6 in. diameter have steel plate working chambers; all other caissons are of concrete with a cutting edge of a 4 in. by 4-in. angle which was riveted to a 9-in. or 10-in. channel.

Grillages are used under most of the columns to distribute the load on the foundations. The grillage under the most heavily loaded column is made up of three tiers of I-beams, the lowest consisting of thirteen 20 in. by 65-lb. I-beams 13 ft. 6 in. long, the middle tier of thirteen 24 in. by 100-lb. I-beams 13 ft. 6 in. long, with each flange reinforced by two 8 in. by ½-in. plates, and the top tier of eight 24 in. by 100-lb. I-beams 11 ft. 6 in. long with each flange reinforced by one 8 in. by $\frac{9}{16}$ in., and one 8 in. by ½-in. plates. The other foundations have granite caps. Cast-iron or cast-steel bases are used under all columns. The cast-steel

base under the column above mentioned is 6 ft. 6 in. square, 3 ft. 3 in. high, and weighs 17 433 lb.

The columns are of regular built-up sections, though some of them are of unusual proportions due to the heavy loads carried. The most heavily loaded column is on the southerly side of Chambers Street near Park Row, and will carry a load of 6 528 600 lb. It is made up of eight angles 8 in. by 6 in. by 1 in., nine plates 20 in. by $\frac{7}{8}$ in., and eight cover plates 40 in. by $\frac{3}{4}$ in., a total area of 501.5 sq. in.

The foundations for the short columns supporting only the mezzanine and street floors were made by driving metal sheet piling, excavating to about elevation — 11 ft., and filling with concrete.

In sinking the caissons it was found that the smaller ones being carried to rock had a greater tendency to shift out of place after the cutting edge had reached from — 60 to — 70 ft.

A station of the Centre Street subway occupies the greater part of the basement of the building, with base of rail at elevation — 2.575 ft. at the southerly end and on a grade of 0.5 per cent. downward toward the north. This fixes the elevation of the floor of the boiler-room, which occupies the space east of the station, at + 0.5 ft., or a little below the station platforms.

The floor of the space between the new subway station and the present subway, which will be used as a pump-room, is placed at + 9 ft., or approximately the level of the present subway, thus affording a bench of varying width as a protection for this subway. Steel sheet piling was also driven alongside the subway wall to a level about nine feet below the excavation as a further protection.

Previous to the contract for the foundations, a test was made of the bearing power of the sand by sinking a 15-in. pipe and removing the sand from within and slightly below the bottom of the pipe, then inserting in it a 10-in. pipe having a disc at its lower end, with an area of 1.069 sq. ft.

The ground-water level was found to be constant at elevation — 5.7 ft. and uninfluenced by the tides.

The first test was made at elevation — 16.6 ft., with a load gradually increased to 31 900 lb., extending over a period of fourteen days, and with a settlement of $\frac{1}{4}$ in. The second test was made at

elevation — 26.6 ft. under the same conditions, the maximum load being 32 430 lb., the time of observation seventeen days, and the total settlement ½ in. The third test was made at elevation — 43.5 ft., with the following results:

Date.	Load.	Settlement, in Inches.	
		Due to previous load.	After this load was applied.
1908.			
Sept. 24	16 270 lb.	.....	11/32
" 26	32 270 "	13/32	23/32
" 30	36 270 "	3/32	13/16
" 30	38 270 "	1/32	27/32
" 30	39 270 "	.....	27/32
" 30	40 270 "	.....	7/8
" 30	41 270 "	.....	1 1/32
" 30	42 270 "	.....	1 1/16
" 30	43 270 "	.....	1 3/32
" 30	44 270 "	.....	1 1/8
" 30	46 270 "	.....	1 3/16
" 30	47 270 "	.....	1 7/32
" 30	48 270 "	.....	1 9/32
Oct. 5	50 270 "	1 3/32	1 11/32
" 5	52 270 "	.....	1 13/32
" 5	54 270 "	.....	1 15/32
" 5	56 270 "	.....	2 3/32
" 5	58 270 "	.....	2 1/16
" 5	60 270 "	.....	2 7/32
Nov. 20	60 270 "	.....	2 11/32

After completion, one of the foundations resting on sand was first loaded to six tons per square foot with a settlement of ½ in., and allowed to rest for seven days with no further settlement, after which the load was increased to ten tons per square foot, with a futher settlement of 7/16 in. Upon removing the test load there was no rise of the foundation.

As there will undoubtedly be other visits to the building during its construction, a description of the building proper is left to the future.

Centre Street Subway.

The Centre Street Subway, which is intended to form a connecting link between the Williamsburgh and Brooklyn Bridges, with a spur to the Manhattan Bridge, and provision for an extension through William Street, is complete except for that portion under and near the Municipal Building.

This subway has four tracks, the use of which has not yet been fully determined, and two stations besides the one in the Municipal

Building. These stations are located at Canal Street and Centre Street and at the Bowery and Delancey Street, each having two island platforms with the tracks on either side. At Canal Street the subway is depressed to the second level to provide for a possible cross-town subway, and an escalator is provided on each platform to take passengers up to the mezzanine floor.

A marked deviation from the other subways is that the spur to the Manhattan Bridge makes a grade connection with the two easterly tracks of the main line instead of crossing under or over these tracks.

The subway is built of steel columns and girders, entirely encased in concrete, the columns being encased in pairs with an arched opening between tracks at every other column. Even the brackets at the tops of the columns are encased with concrete, leaving a triangular opening in which electric wires are to be strung.

The stations were simply and effectively decorated in a manner to distinguish each station, and the ceilings and lighting shafts were covered with a white cement plaster, which added greatly to the illumination of the stations.

The thanks of the Society are due to the Bradley Contracting Company, which furnished the lights and escorted the party through the subway.

MEMOIRS OF DECEASED MEMBERS.

SAMUEL R. PROBASCO.

Samuel R. Probasco was born in the old City of New York, September 13th, 1833, and died at his home in the City of Burlington, New Jersey, on the 19th day of January, 1910.

He was educated in the public schools, and in 1854, during the California gold fever, he went to San Francisco by way of Cape Horn. While there, he was a member of the Second Vigilance Committee.

He returned to New York in 1856 and studied engineering. He was on the construction of the old Albany Bridge, under Colonel Julius W. Adams. Subsequently, from 1871 to 1875, he was Principal Assistant Engineer under the Water Board of the City of Brooklyn. At this time he was in charge of the construction of the Storage Reservoir at Hempstead, Lond Island, and as Deputy to Colonel Julius W. Adams, he was in charge of all details of work on the watershed. He was also in charge of paving and repaving, and for some time was in charge of sewer construction in the old City of Brooklyn. In 1868 he made preliminary surveys for the New York and Brooklyn Bridge, and in 1875, became one of the assistant engineers of the New York and Brooklyn Bridge. He remained with the Department of Bridges, the successor to The Trustees of the New York and Brooklyn Bridge, up to the time of his death.

In 1898, after consolidation, he was appointed by the Commissioner of Bridges Chief Engineer of the Department, and remained in that position until 1901, when he resigned and was transferred to the New York and Brooklyn Bridge. He was appointed one of the consulting engineers, by Bridge Commissioner Lindenthal, during 1902 and 1903. During his connection with the Brooklyn Water Works he invented the modern process of casting curved specials for water pipe.

In 1858 he married Anna M. Phillips, of Lumberton, New Jersey, who survives him, together with his sons, Selden R. Probasco, an engineer of Burlington, New Jersey, and Samuel K. Probasco, a lawyer of this City.

He was a member of the American Society of Civil Engineers, The Municipal Engineers, The Brooklyn Club and The Long Island Historical Society, of which he was one of the regents.

FRANK J. WILFORD.

Frank Jay Wilford was born in the City of New York on March 29, 1862, and died on March 11, 1910, at his home in Brooklyn.

He was educated at the De La Salle Institute, and at an early age distinguished himself as an expert penman and artist. In 1888 he accepted a position in the Register's office, where he remained 4 years. In 1892 he entered the service of the Department of Taxes and Assessments as draftsman, which position he held at the time of his death.

On May 22, 1907, he became a member of the Municipal Engineers. He was also President of the Philadelphia Society of New York and Vice-President of the Eckford Club. He was much interested in literary and elocutionary work, and was a notable stamp and coin collector.

He was never married, but made his home with his sister at 84 Morton St., Brooklyn.

HERBERT BURNS COFFMAN.

Herbert Burns Coffman was born in 1862, in the State of Ohio, and died on May 4th, 1910. At the time of his death, and for some 12 years previous, he was engaged as Inspector of Iron and Steel in the Building Bureau, Board of Education, and for 10 years previous to his entering the City service he was employed in a similar capacity on many of the large buildings of the country, among which were the Masonic Temple, Auditorium Annex and the Marshall Field Building of Chicago, the Court House at Fort Worth, Texas, McCormack Bank Building, Salt Lake City, Utah, and many others of a similar nature.

He was a charter member of the Municipal Engineers.

INFORMATION.

MEETINGS.—Regular meetings are held in the Engineering Societies Building, No. 29 West 39th Street, Manhattan, on the fourth Wednesday of each month at 8:30 P. M., except in June, July and August. The Annual Meeting is held on the fourth Wednesday in January.

LIBRARY.—The Society rooms and library are open every day and evening, including Sundays and holidays. Keys may be obtained from the Secretary on the deposit of 25 cents each.

Members of the Society and all who feel an interest in the maintenance of a technical reference library, devoted more especially to the subject of municipal engineering, are asked to donate engineering books, reports, specifications, maps, plans and photographs.

PROCEEDINGS.—The Society issues one volume of PROCEEDINGS each year, usually in May. It contains all of the papers presented during the preceding year, the annual address of the President, the final reports of special committees on professional subjects, descriptions of the works visited by the Society, and the speeches delivered at the annual banquet, which are of permanent value.

Proceedings are furnished without extra charge to members, and are sold for $2.00 in cloth and $1.50 in paper. Exchanges are desired with other societies, libraries, colleges, etc.

PAPERS.—Papers and discussions on subjects of engineering interest are invited from all persons, whether members of the Society or not. They are, of course, subject to proper editorial supervision. All papers on their acceptance become the property of the Society.

BADGES.—The badge of the Society is of gold with blue enamel in the design shown on the title page of this book. It has a number engraved upon the back, and may be obtained as a pin, a watch charm, or a button. The price is $4.00. Application for it should be made to the Secretary.

CERTIFICATES OF MEMBERSHIP.—The certificate of membership is steel-engraved on parchment paper, engrossed with the name of the member and the date of his election; the seal of the Society is impressed, and it is signed by the President and Secretary. The size is 14 by 18 inches, and the price is $2.00. Application for it should be made to the Secretary.

DUES.—The dues for Resident Membership are $10.00 a year, for Non-resident Membership, $5.00 a year.

REMITTANCES.—All remittances should be made payable to the order of Municipal Engineers. They should be made by check on New York or by post-office or express money order payable at New York.

ABBREVIATION FOR MEMBER.—The Board of Directors has authorized the use of the abbreviation "M. M. E. N. Y.," to signify "Member of the Municipal Engineers of the City of New York."

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SECRETARIES

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AWARD OF PRIZES.

These papers will be found in the Proceedings for the years indicated.

1903.

JAMES COPPER BAYLES, M. M. E. N. Y., for paper entitled: The Problem of the Maintenance of Asphalt Pavements in Manhattan.

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SIDNEY WILLETT HOAG, Jr., M. M. E. N. Y., for paper entitled: The Dock Department and the New York Docks.

1906.

ALFRED DOUGLAS FLINN, M. M. E. N. Y., for paper entitled: The Organization of an Engineering Force in New York City.

1907.

EDWARD HENRY HOLDEN, M. M. E. N. Y., for paper entitled: Traverse Work in Connection with the Triangulation of Bronx Borough.

1908.

ROBERT RIDGWAY, M. M. E. N. Y., for paper (Northern Aqueduct Department) entitled: Subsurface Investigations of the Board of Water Supply for the Proposed Catskill and Long Island Aqueducts and Reservoirs.

1909.

THOMAS HOLLIS WIGGIN, M. M. E. N. Y., for paper entitled: The Design of Pressure Tunnels of the Catskill Aqueduct.

PAST PRESIDENT MEDALS.

NELSON PETER LEWIS	1903-4
SAMUEL CLARENCE THOMPSON	1905
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ARTHUR SMITH TUTTLE	1910

INDEX TO PREVIOUS VOLUMES.

PROCEEDINGS FOR 1903.

PAGE

PAPER NO. 1.—PARK ENGINEERING IN THE BOROUGHS OF MANTAN AND THE BRONX, BY NELSON P. LEWIS, M. M. E. N. Y. 7

PAPER NO. 2.—THE OLD ROMAN AQUEDUCTS, BY EDWARD WEGMANN, M. M. E. N. Y. 26

PAPER NO. 3.—RAPID TRANSIT IN NEW YORK CITY, BY GEORGE S. RICE, M. M. E. N. Y. 62

PAPER NO. 4.—SOME STREET TRAFFIC PROBLEMS, BY WISNER MARTIN, M. M. E. N. Y. 74

PAPER NO. 5.—THE PROBLEM OF THE MAINTENANCE OF ASPHALT PAVEMENTS IN MANHATTAN,* BY JAMES C. BAYLES, M. M. E. N. Y. 80

PAPER NO. 6.—THE INVESTIGATION OF SOURCES OF WATER SUPPLY IN THE CITY OF NEW YORK, TOPICAL DISCUSSION BY A. S. TUTTLE, M. M. E. N. Y.; W. W. BRUSH, M. M. E. N. Y., AND D. D. JACKSON, M. M. E. N. Y. 100

PROCEEDINGS FOR 1904.

PAPER NO. 7.—INVESTIGATION FOR THE NEW WATER SUPPLY OF THE CITY OF NEW YORK, BY WILLIAM H. BURR, M. M. E. N. Y. 5

PAPER NO. 8.—THE MAINTENANCE AND REPAIRS OF ASPHALT PAVEMENT,* BY GEORGE W. TILLSON, M. M. E. N. Y. 20

PAPER NO. 9.—THE CONSTRUCTION OF PUBLIC SCHOOL BUILDINGS IN THE CITY OF NEW YORK, BY C. B. J. SNYDER, M. M. E. N. Y. 46

PAPER NO. 10.—HARLEM RIVER BRIDGES, BY MARTIN GAY, M. M. E. N. Y. 67

PAPER NO. 11.—THE HISTORY AND DEVELOPMENT OF THE TOPOGRAPHICAL WORK OF THE CITY OF NEW YORK, BY FREDERICK GREIFFENBERG, M. M. E. N. Y., AND WILLIAM S. DALRYMPLE 83

PAPER NO. 12.—PLANS AND SPECIFICATIONS, BY J. V. DAVIES .. 105

PAPER NO. 13.—SUBAQUEOUS WATER MAINS, BY WILLIAM D. LINTZ, M. M. E. N. Y. 130

PAPER NO. 14.—CHEMICAL PRECIPITATION PLANS, CONTACT BEDS AND SEPTIC TANKS AS CONSIDERED IN A DESIGN FOR A PORTION OF BROOKLYN'S SEWERS, BY HENRY R. ASSERSON, M. M. E. N. Y. 155

* Prize paper.

PROCEEDINGS FOR 1905.

PAGE

PAPER NO. 15.—THE NEW CROTON AQUEDUCT, BY EDWARD WEGMANN, M. M. E. N. Y., EXPERT ENGINEER, AQUEDUCT COMMISSIONERS 3

PAPER NO. 16.—THE DOCK DEPARTMENT AND THE NEW YORK DOCKS,* BY SIDNEY W. HOAG, JR., M. M. E. N. Y., ASSISTANT ENGINEER, DEPARTMENT OF DOCKS AND FERRIES.. 31

PAPER NO. 17.—THE ENGINEER'S FAULT, BY JOHN C. WAIT, M. M. E. N. Y., COUNSELOR AT LAW..... 156

PAPER NO. 18.—REPORT OF THE SPECIAL COMMITTEE ON DATUM PLANES, BY LAZARUS WHITE, M. M. E. N. Y., ASSISTANT ENGINEER, RAPID TRANSIT COMMISSIONERS..... 206

PAPER NO. 19.—THE DESIRABILITY OF COMPREHENSIVE MUNICIPAL PLANNING IN ADVANCE OF DEVELOPMENT, BY CALVIN TOMPKINS, FORMER PRESIDENT OF THE MUNICIPAL ART SOCIETY..... 226

PAPER NO. 20.—THE PROPOSED MUNICIPAL LIGHTING PLANT, BY GEORGE F. SEVER, M. M. E. N. Y., CONSULTING ELECTRICAL ENGINEER, DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY, AND MEMBER OF THE MAYOR'S COMMITTEE OF EXPERTS..... 238

PAPER NO. 21.—HISTORY AND DEVELOPMENT OF THE PLANE TABLE, BY EDWARD M. LAW, JR., M. M. E. N. Y., ASSISTANT ENGINEER, OFFICE OF THE BOROUGH PRESIDENT OF RICHMOND..... 255

REPORT OF THE SPECIAL COMMITTEE ON COST OF REPAIRS TO ASPHALT PAVEMENTS, GEORGE W. TILLSON, M. M. E. N. Y., CHAIRMAN..... 277

PROCEEDINGS FOR 1906.

PAPER NO. 22.—THE SUBSTRUCTURE OF THE HOUSATONIC RIVER BRIDGE AT NAUGATUCK JUNCTION, CONN., BY CAMILLE MAZEAU, ASSISTANT ENGINEER, NEW YORK, NEW HAVEN AND HARTFORD RAILROAD..... 5

PAPER NO. 23.—THE MANHATTAN BRIDGE, ITS TERMINALS AND CONNECTIONS, BY OTHNIEL F. NICHOLS, M. M. E. N. Y., CONSULTING ENGINEER, DEPARTMENT OF BRIDGES..... 16

PAPER NO. 24.—THE TESTING OF MATERIAL BY THE BUREAU OF BUILDINGS FOR MANHATTAN, BY RUDOLPH P. MILLER, M. M. E. N. Y., ASSISTANT ENGINEER, BUREAU OF BUILDINGS, MANHATTAN..... 41

PAPER NO. 25.—RECENT DEVELOPMENTS IN WOOD BLOCK PAVING, BY FREDERICK A. KUMMER, ENGINEER, UNITED STATES WOOD PRESERVING COMPANY..... 58

* Prize paper.

PAGE

PAPER NO. 26.—THE HIGH PRESSURE FIRE SERVICE IN MANHATTAN, BY IGNACIO M. DE VARONA, M. M. E. N. Y., CHIEF ENGINEER, DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY..... 83

PAPER NO. 27.—THE ORGANIZATION OF AN ENGINEERING FORCE IN NEW YORK CITY,* BY ALFRED D. FLINN, M. M. E. N. Y., DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY..... 21

PAPER NO. 28.—FOUNDATIONS FOR SKYSCRAPERS, BY JOHN W. DOTY, ENGINEER, FOUNDATION COMPANY..... 140

PAPER NO. 29.—TUNNELLING UNDER COMPRESSED AIR WITH SHIELDS, BY ST. JOHN CLARKE, M. M. E. N. Y., CHIEF ENGINEER, NEW YORK AND LONG ISLAND RAILROAD COMPANY..... 157

PROCEEDINGS FOR 1907.

PAPER NO. 30.—CONSTRUCTION DETAILS OF REINFORCED CONCRETE WORK, BY DE FOREST H. DIXON, SECRETARY, TURNER CONSTRUCTION COMPANY..... 5

PAPER NO. 31.—THE GEOLOGY OF LONG ISLAND AND ITS PRACTICAL RELATION TO UNDERGROUND WATER SUPPLIES, BY ALEXANDER SIMPSON FARMER, M. M. E. N. Y., ASSISTANT ENGINEER, AQUEDUCT COMMISSIONERS..... 24

PAPER NO. 32.—SOME NOTES ON MUNICIPAL CLEANING AND REFUSE DESTRUCTION, BY JOHN TURNEY FETHERSTON, M. M. E. N. Y., SUPERINTENDENT OF STREET CLEANING, BOROUGH OF RICHMOND..... 47

PAPER NO. 33.—THE RELATION OF SANITARY SCIENCE TO MUNICIPAL ENGINEERING, BY GEORGE A. SOPER, M. M. E. N. Y., CONSULTING SANITARY EXPERT, PUBLIC SERVICE COMMISSION..... 70

PAPER NO. 34.—TRAVERSE WORK IN CONNECTION WITH THE TRIANGULATION OF THE BRONX BOROUGH,* BY EDWARD H. HOLDEN, M. M. E. N. Y., ASSISTANT ENGINEER IN CHARGE OF SURVEYS AND MONUMENTING, TOPOGRAPHICAL BUREAU, BOROUGH OF THE BRONX..... 81

PAPER NO. 35.—THE DESIRABILITY OF CENTRALIZED ENGINEERING CONTROL FOR NEW YORK CITY, BY M. N. BAKER, EDITOR, ENGINEERING NEWS..... 104

PAPER NO. 36.—THE SOUTHERLY EXTENSION OF NEW YORK CITY, BY HERMAN ARNOLD RUGE, M. M. E. N. Y., OF THE DEPARTMENT OF DOCKS AND FERRIES..... 121

PAPER NO. 37.—THE DESIGNING, MAKING AND TESTING OF A TELESCOPE, BY F. KOLLMORGEN, OPTICAL EXPERT, KEUFFEL & ESSER COMPANY..... 134

* Prize paper.

PROCEEDINGS FOR 1908.

PAGE

PAPER NO. 38.—THE PROPOSED FILTRATION OF THE CROTON WATER SUPPLY OF NEW YORK CITY, BY WILLIAM B. FULLER, M. M. E. N. Y., CONSULTING CIVIL ENGINEER.... 4

PAPER NO. 39.—SUBSURFACE INVESTIGATIONS OF THE BOARD OF WATER SUPPLY FOR THE PROPOSED CATSKILL AND LONG ISLAND AQUEDUCTS AND RESERVOIRS,* BY DWIGHT S. MALLETT, M. M. E. N. Y.; ROBERT RIDGWAY, M. M. E. N. Y.; WILSON FITCH SMITH, AND WALTER E. SPEAR, M. M. E. N. Y., ENGINEERS OF THE BOARD OF WATER SUPPLY..... 31

PAPER NO. 40.—THE POSSIBILITIES OF THE ESTHETIC DEVELOPMENT OF OUR CITY, BY CHARLES ROLLINSON LAMB, ARCHITECT..... 87

PAPER NO. 41.—THE SEWERAGE PROBLEM OF THE BOROUGH OF QUEENS, BY ALBERTO SCHREINER, M. M. E. N. Y., ASSISTANT ENGINEER, BUREAU OF SEWERS, BOROUGH OF QUEENS.. 115

PAPER NO. 42.—BENCH LEVELS AND NEW YORK CITY DATUMS, BY CHARLES GOODMAN, M. M. E. N. Y., ASSISTANT ENGINEER, BOARD OF WATER SUPPLY..... 130

PAPER NO. 43.—MUNICIPAL WATER-WORKS OF THE FAR EAST, BY GEORGE A. JOHNSON, OF FIRM OF HERING & FULLER, CONSULTING ENGINEERS..... 183

PAPER NO. 44.—WATERPROOFING—AN ENGINEERING PROBLEM, BY MYRON H. LEWIS, M. M. E. N. Y., ASSISTANT ENGINEER, TOPOGRAPHICAL BUREAU, BOROUGH OF QUEENS..... 208

PAPER NO. 45.—THE ST. GEORGE FERRY APPROACH AND REINFORCED CONCRETE RETAINING WALL, BY LOUIS L. TRIBUS, M. M. E. N. Y., COMMISSIONER OF PUBLIC WORKS AND CONSULTING ENGINEER, BOROUGH OF RICHMOND..... 261

APPENDIX TO PAPER NO. 34.—NEW INSTRUMENTS FOR PRIMARY TRAVERSE WORK, BY EDWARD H. HOLDEN, M. M. E. N. Y., ASSISTANT ENGINEER IN CHARGE OF SURVEYS AND MONUMENTING, TOPOGRAPHICAL BUREAU, BOROUGH OF THE BRONX..... 278

PROCEEDINGS FOR 1909.

PAPER NO. 46.—AN ADDITIVE METHOD OF RUN-OFF DETERMINATION FOR STORM-WATER SEWERS, BY CARL H. NORDELL, M. M. E. N. Y., BUREAU OF SEWERS, BOROUGH OF QUEENS. 5

PAPER NO. 47.—SOME INTERESTING AMERICAN TREES, BY HERMAN W. MERKEL, CHIEF FORESTER, NEW YORK ZOOLOGICAL PARK..... 36

* Prize paper, portion by Mr. Robert Ridgway.

PAPER NO. 48.—IMPROVEMENTS OF THE APPEARANCE OF MUNICIPALITIES, BY CHARLES W. LEAVITT, JR., LANDSCAPE ENGINEER, NEW YORK CITY..... 53
PAPER NO. 49.—THE SANITARY PROTECTION OF WATER SUPPLIES, BY NICHOLAS S. HILL, JR., M. M. E. N. Y., CONSULTING ENGINEER, NEW YORK CITY..... 64
PAPER NO. 50.—CONSTRUCTION PROBLEMS OF THE BROOKLYN SUBWAY, BY JAMES C. MEEM, CHIEF ENGINEER, CRANFORD & MCNAMEE..... 91
PAPER NO. 51.—THE DESIGN OF PRESSURE TUNNELS OF THE CATSKILL AQUEDUCT,* BY THOMAS H. WIGGIN, M. M. E. N. Y., SENIOR DESIGNING ENGINEER, BOARD OF WATER SUPPLY 99
PAPER NO. 52.—THE NEW YORK STATE BARGE CANAL, BY FREDERICK SKENE, M. M. E. N. Y., CONSULTING ENGINEER, NEW YORK CITY..... 150
PAPER NO. 53.—THE REDUCTION OF THE WATER TABLE AND ITS EFFECT ON FOUNDATIONS IN NEW YORK CITY, BY FRANCIS L. PRUYN, VICE-PRESIDENT OF THE UNDERPINNING CO., AND CONSULTING ENGINEER, NEW YORK CITY..... 161

* Prize paper.

INDEX TO ADVERTISEMENTS.

Atlas Portland Cement Co..... 21

Borne, Scrymser Co..... 4
Barrett Manufacturing Co..... 8
Baird & Sons, Andrew D..... 9
Brooklyn Alcatraz Asphalt Co..... 11
Booth Brothers & Hurricane Isle Granite Co..... 21
Barber Asphalt Paving Co 22
Burke & Sons Co., Inc., Luke A..... 24
Brandis Sons & Co., F. E..... 27

Croton Falls Construction Co..... 3
Cossey, Harry..... 26
Chicago Bridge & Iron Works..... 28

Donegan-Redmond Co..... 10

Engineering News Publishing Co..... 1
Eddy & Co , George M..... 12
Evening Post Job Printing Office, The 19

Fox & Co., John..... 15
Fitzgerald, W. J..... 28

Hastings Pavement Co..... 16
Harlem Contracting Co..... 18
Hudson River Blue Stone..... 25
Hyde, E. Belcher..... 26

Johns-Manville Co., H. W..... 2
Johnson's Sons, Joseph..... 5

Keasbey Co., Robert A..... 5

Lufkin Rule Co..... 11
Lorillard Refrigerator Co..... 25

Mineral Wool Co., U. S..... 10
Mundy, J. S..... 12
McCoy Co., Henry J..... 20
Murphy Brothers..... 29

New York Steam Co..... 10

Phœnix Towing & Transportation Co. 9
Pullis, P. P..... 20

Rodgers & Hagerty..... 2
Rail Joint Co..... 4
Roebling's Sons Co., John A..... 17
Remington Typewriter Co..... 26
Rockport Granite Co..... 28
Raymond Concrete Pile Co..... 28

Snare & Triest Co..... 18
Sicilian Asphalt Paving Co..... 14
Schrader's Sons Inc., A..... 20
Sterling Engraving Co..... 25

Texas Co..... 6

Underwood Typewriter Co..... 3
United Building Material Co..... 12

Wood Preserving Co., U. S..... 7
Williamson, F. Stuart..... 11

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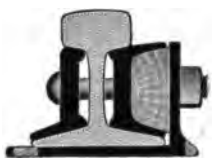

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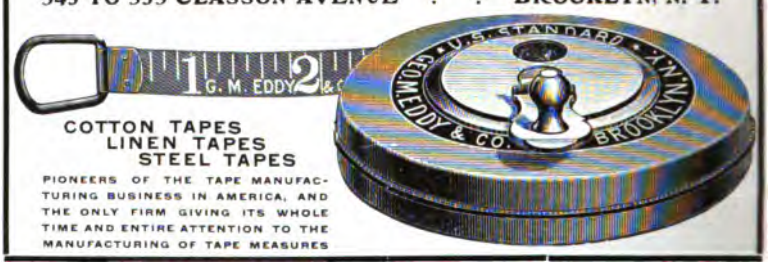

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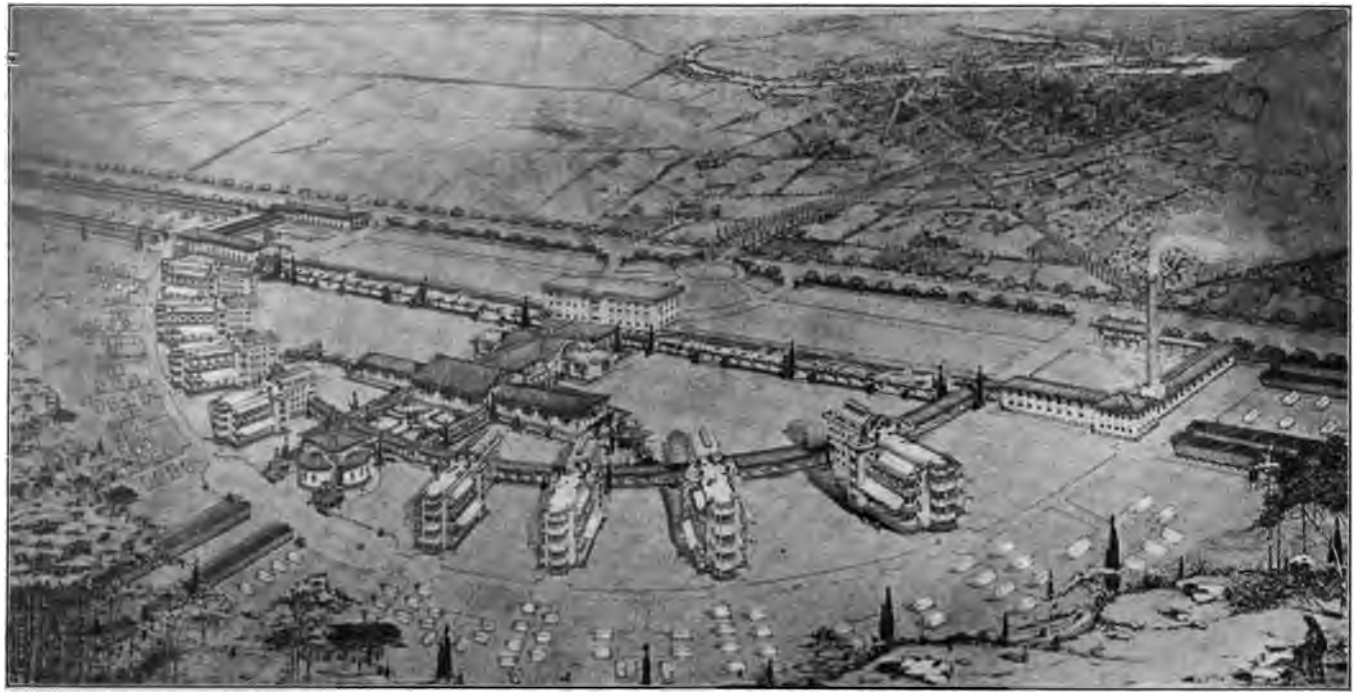

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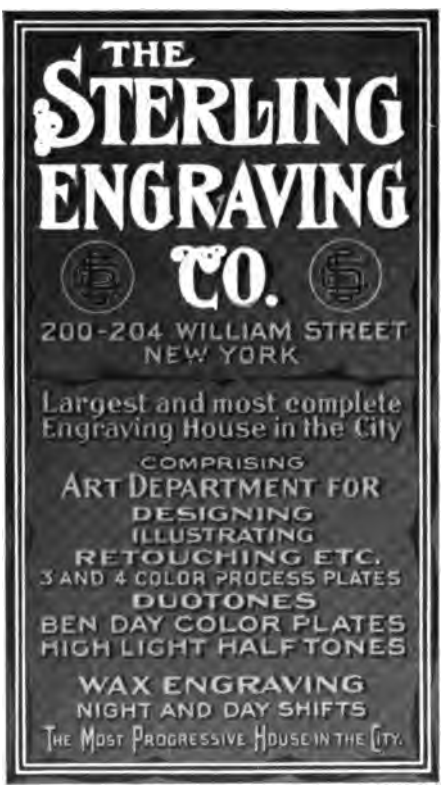

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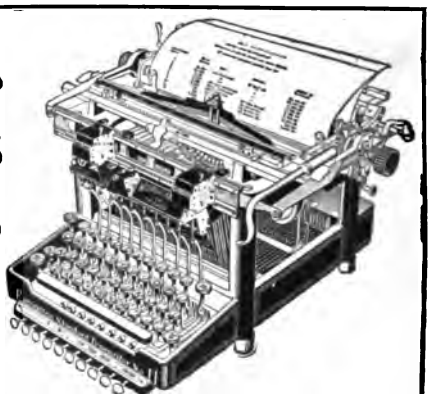

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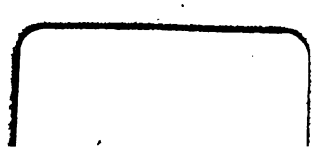
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